DAYBREAK.

A wind came up out of the sea
And said, "O mists, make room for me!"

It hailed the ships, and cried, "Sail on,
Ye mariners, the night is gone."

And hurried landward far away,
Crying, "Awake! it is the day."

It said unto the forest, "Shout!
Hang all your leafy banners out!"

It touched the wood-bird's folded wing,
And said, "O bird, awake and sing!"

And o'er the farms, "O chanticleer,
Your clarion blow; the day is near!"

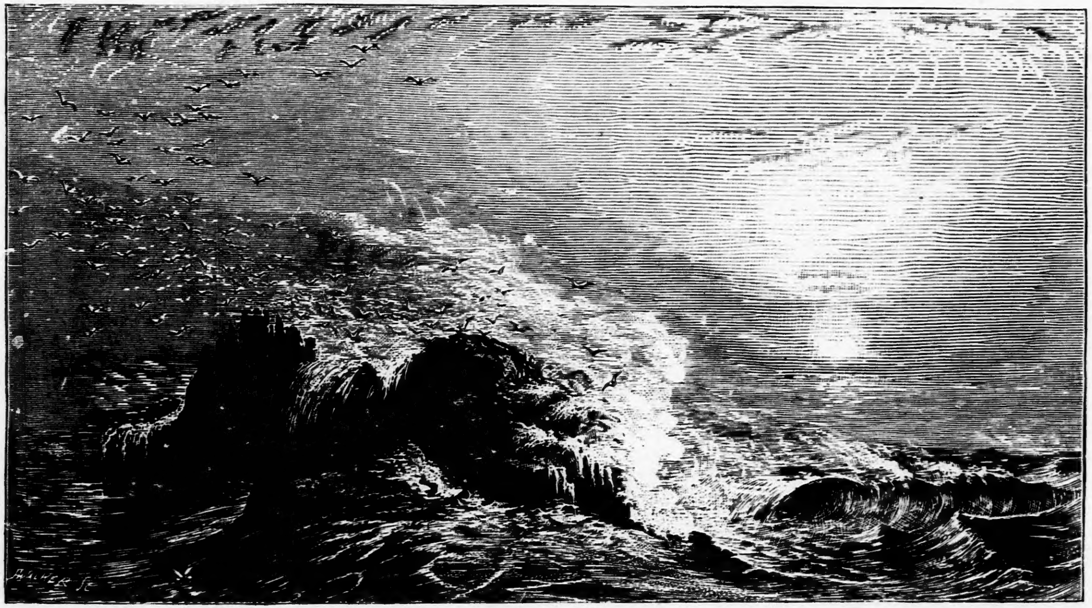
It whispered to the fields of corn,
"Bow down, and hail the coming morn!"

It shouted through the belfry-tower,
"Awake, O bell! proclaim the hour."

It crossed the churchyard with a sigh,
And said, "Not yet! in quiet lie."

H. W. LONGFELLOW.

DAY-BREAK.



From a painting by —. Tracey.

PART THIRD.

SUPPLEMENT D.

PART THIRD.

CENTRIFUGAL FORCE

AND

GRAVITATION.

SUPPLEMENT D.

PART THIRD.

CENTRIFUGAL FORCE

AND

GRAVITATION.

A LECTURE.

BY

JOHN HARRIS.

MONTREAL:
JOHN LOVELL, ST. NICHOLAS STREET.

DECEMBER, 1873.

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LIGHT.

It has been shown in the earlier part of this work that the angular velocity of a planet is in simple inverse proportion to the distance of that planet from the sun; and it, therefore, follows that the distance is inversely proportional to the angular velocity. Herein, assuming that the correct distance of the earth from the sun has been obtained and that the synodic periods of the planets have been correctly observed, we have a simple and reliable means whereby to compute the distance of any given planet from the sun.

To apply this method to the case of the planet Venus we have

1. The distance of the earth from the sun..................	=	95 million miles.
2. The synodic period, namely, the time ascertained by observation to elapse from one conjunction to the next *similar* conjunction............	=	584 days.

Since the earth requires 365 days to complete one revolution, or, in other words, to revolve through 360° of orbit; 584 days will represent a revolution through 576° of orbit. The question, in the first place, is, therefore, how many degrees of orbital revolution of Venus are represented by the same period of time. Since the orbit of Venus is within that of the earth, its angular velocity must be greater, and, therefore, in the time required by the earth to complete a revolution, more than a complete revolution will have been made by Venus. But, as the distance of Venus from the sun is known to be certainly greater than half that of the earth, the planet's angular velocity will be less than two revolutions

to one of the earth. Let us, therefore, in the first instance, assume that the proportion may be $1\frac{1}{2}$ revolutions of the planet to 1 revolution of the earth.

We then obtain :—

1 revolution of earth	=	360°	equals $1\frac{1}{2}$ revolution of Venus........	= 540°
$\frac{1}{2}$ " " "	=	180°	equals $\frac{3}{4}$ revolution of Venus........	= 270°
Remainder of synodic revolution of earth..........	=	36°	equals proportion of Venus.......	= 54°
		576°		864°

But for conjunction to take place, the number of degrees measuring from the completion of the circle (revolution) by each of the two bodies (earth and Venus), must correspond; and on comparison we have a difference, after deducting 1 revolution of the earth, and two revolutions of Venus, of 72°.

Thus :—

$$576—360 = 216$$
$$864—720 = 144$$
$$72°$$

Consequently the velocity thus attributed to the planet is rather less than the actual velocity; the quantity by which it is less, is readily obtainable and gives $(1\frac{1}{2} + \frac{1}{8})$: 1 *i.e.*, $1\frac{5}{8}$: 1 as the correct proportion :—

Earth.			Venus.		
1 revoln.	= 360°	equals	$1\frac{5}{8}$ revoln.		= 585°
$\frac{1}{2}$ do	= 180°	equals	$\frac{1\frac{5}{8}}{2}$	do	= $292\frac{1}{2}$°
Remainder of Synodic revol.	= 36°	equals		do	= $58\frac{1}{2}$°
	576°				936°

Showing that *at this point* conjunction would again take place. Now, since the distance is inversely as the angu-

lar velocity, we have only to take the distance of the earth, and to invert the proportion in order to obtain the distance of the planet from the sun.

Thus

As $1\frac{5}{8}$: 1 : : distance of earth : distance of planet.

(*i.e.*) As 95,000,000 miles is to 58,461,540 miles—which is, therefore, the distance of the planet from the sun (supposing the estimated distance of the earth from the sun to be correct.)

But, on referring to Lardner's Astronomy, we find the distance given is

about $68\frac{1}{2}$ millions of miles,

a difference, therefore, of 10 millions of miles.

Lardner's Astronomy—The Planet Venus.

2670. " *The synodic period*, ascertained by observation, is. . . .584 days.

2672. *Distance by greatest elongation.*—The mean amount of greatest elongation of Venus being found, by observation, to be about 45° or 46°, it follows that, in that position, lines drawn to the earth, and seen from the planet, would form the sides of a square, of which the earth's distance from the sun is the diagonal. If, therefore, the earth's distance be expressed by 1·0000, that of Venus would be 0·7071.

2673. *By the harmonic law.*—If r express the mean distance of the planet from the sun, we have

$$r^3 = 0{\cdot}61^2 = 0.719. \quad \text{Therefore } r = 0{\cdot}719;$$

and since the mean distance of the earth is 95 millions of miles, we shall have

$$r' = 95{,}000{,}000 \times 0{\cdot}719 = 68{,}300{,}000.$$

By more exact methods the distance is found to be $68\frac{3}{4}$ millions of miles."

2674. "*Mean and extreme distances from the Earth.*—Its distances from the earth at inferior conjunction, greatest elongation, and superior conjunction are therefore:—

26,250,000 miles at inf. conj.
65,000,000 miles at greatest elong.
163,750,000 miles at super. conj.

The eccentricity of the orbit of Venus being less than 0.007, these distances are subject to very little variation from that cause.

"The extreme distance of the planet from the sun will be $68\frac{3}{4} + 0\frac{1}{2} = 68\frac{1}{4}$ millions of miles in perihelion,

$68\frac{3}{4} + 0\frac{1}{2} = 69\frac{1}{4}$ " " " " aphelion.

These distances of the planet from the earth are subject, therefore, to an increase and diminution, amounting to half a million of miles, due to the eccentricity of the planet's orbit, and one and a half million of miles due to that of the earth's orbit.

2675. *Scale of the orbit relative to that of the earth.*—The relation of the orbit of Venus to the earth is represented in Fig. 750, where *S. E.* represents the earth's distance from the sun, and *v. S. v.* the mean diameter of the planet's orbit on the same scale. The angles *S. E. v.″* represent the greatest elongation of the planet, which is about 46°. The lesser elongations *v.‴ E. S.* are those at which the planet appears with less than a full disc, or gibbous, as at *v.‴*, or as a crescent, as at *v.′*

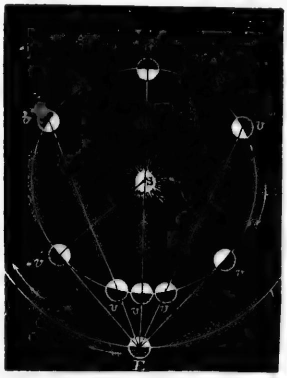


Fig. 750.

2676. *Apparent motion.*—Since the mean value of the greatest elongation is ascertained to be 46°, the angle at "

"the sun $v.''$ $S. E.$ = 44°, and consequently the angle $v.''$ $S.v.''$ included between the greatest elongation east and west is 88°. Since the time taken by the planet to gain this angle upon the earth bears the same ratio to the synodic period as this angle bears to 360°, the intervals into which the synodic period is divided by the epochs of greatest elongation, are

$$\frac{88}{360}\times 584 = 142{\cdot}8 \text{ days.}$$

$$\frac{272}{360}\times 584 = 441{\cdot}2 \text{ days.}$$

The intervals between inferior conjunction and greatest elongation are therefore 71½ days, and the intervals between superior conjunction and greatest elongation are 220½ days.

2680. *Apparent diameter.*—Owing to the great difference between its distance from the earth at inferior and superior conjunctions, the apparent diameter of this planet varies in magnitude within wide limits. At superior conjunction it is only 10°, from which to inferior conjunction it gradually enlarges until it becomes 62″, and in some positions even so much as 76″. At its greatest elongation its apparent diameter is about 25″ and its mean distance 16½″."

The method of computing the distance from the greatest elongation is unquestionably correct in principle and will necessarily give a correct result, if the circumstances of the case permit the application of the method to be made with a sufficient degree of accuracy. As soon as it is understood that the angle at the sun is the complement of the angle at the earth (together equal to 90°), and that, consequently, if the one is supposed to be 46° or 47° instead of 45°, the other will be only 44° or 43° instead of 45°, it becomes apparent that, any error in the observation of the angle being thus duplicated, a "

considerable degree of accuracy is requisite to obtain even a rough approximation. To appreciate the difficulty (if not the impracticability) of making such measurement accurately by terrestrial observation, it is only necessary to remember the double or compound motion, viz., the diurnal rotation and the orbital revolution, of the earth, which is the station from which the observation has to be made. We therefore conclude that this method cannot, of itself inspire any confidence in the quantity (or quantities) which may result from its application.

The (so-called) (Harmonic Law) is based and dependent upon Kepler's third law 'of the proportion of the squares of the periods to the cubes of the distances.' Now this third law of Kepler's is dependent upon Newton's 'theory of gravitation' and the 'law of equable areas.' But both Newton's theory of 'gravitation' and that of 'equable' areas are now demonstrated to be unsound and are no longer tenable (Lecture, pages 29, 52, 77)* ; consequently the Harmonic Law is itself without support, and can be no longer scientifically considered to furnish support or reliable evidence.

We find that the distance thus given by Lardner has been also adopted by other astronomers, and is, at the present time, considered to be the established distance of the planet Venus from the sun.

Herschel's Outlines of Astronomy.

(467.) "Mercury never attains a greater angular distance from the sun than about 29°, while Venus extends her excursions on either side to about 47°. When they have receded from the sun, *eastward*, to their respective distances, they remain for a time, as it were, immovable *with respect to it;* and are carried along with it in the ecliptic with a motion equal to its own; but pre-"

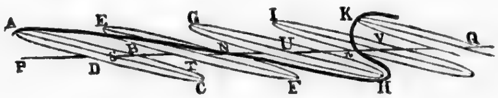
* We state, in the most decided manner, that the demonstrations given by us, as to the unsoundness of those theories, are absolute, and cannot be scientifically impugned.

"sently they begin to approach it, or, which comes to the same, their motion in longitude diminishes and the sun gains upon them. As this approach goes on, their continuance above the horizon after sunset becomes daily shorter, till at length they set before the darkness has become sufficient to allow of their being seen. For a time, then, they are not seen, unless on very rare occasions, when they are to be observed *passing across* the sun's disc, as small, round, well-defined black spots, totally different in appearance from the solar spots. (Art. 386.)

These phenomena are emphatically called *transits* of the respective planets across the sun, and take place when the earth happens to be passing the line of the nodes while they are in that part of their orbits, just as in the account we have given (Art. 412) of a solar eclipse. After having thus continued invisible for a time, however, they begin to appear on the other side of the sun at first showing themselves only for a few minutes before sunrise, and gradually longer and longer as they recede from him. At this time their motion in longitude is rapidly retrograde. Before they attain their greatest elongation, however, they become stationary in the heavens; but their recess from the sun is still maintained by the advance of that luminary along the ecliptic, which continues to leave them behind, until, having reversed their motion, and become again *direct*, they acquire sufficient speed to commence overtaking him—at which moment they have their greatest western elongation; and thus is a kind of oscillatory movement kept up, while the general advance along the ecliptic goes on."

(468.) "Suppose *P.Q.* to be the eliptic, and *A.B.C.D.* the orbit of one of these planets (for instance, Mercury,) seen almost edgewise by an eye situated very nearly in its plane; *S.*, the sun, its centre; and *A. B. C. D.*, successive positions of the planet, of which *B.* and *D.* are"

"in the nodes. If, then, the sun, *S.*, stood apparently still in the ecliptic, the planets would simply appear to oscillate backwards and forwards from *A.* to *C.*, alter-

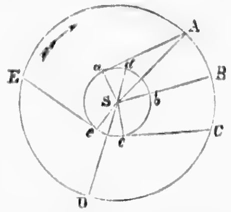


nately passing before and behind the sun; and, if the eye happened to lie exactly in the plane of the orbit, *transitting* his disc in the former case, and being covered by it in the latter. But as the sun is not so stationary, but apparently carried along the ecliptic *P. Q.;* let it be supposed to move over the spaces, *S.T.*, *T.U.*, *U.V.*, while the planet in each case executes one quarter of its period. Then will its orbit be apparently carried along with the sun into the successive positions represented in the figure; and while its real motion round the sun brings it into the respective points *B. C. D. A.*, its apparent movement in the heavens will seem to have been along the wavy or zigzag line *A. N. H. K.* In this, its motion in longitude will have been direct in the parts *A.N.*, *N.H.*, and retrograde in the parts, *H. n. K.;* while at the turns of the zigzag, as at *H.*, it will have been stationary.

(469.) The only two planets—Mercury and Venus—whose revolutions are such as above described, are called inferior planets; their points of farthest recess from the sun are called (as above) their *greatest* eastern and western *elongations;* and their points of nearest approach to it, their *inferior* and *superior* conjunctions, the former when the planet passes between the earth and the sun, the latter when behind the sun.

(470). In Art. 467, we have traced the apparent path of an inferior planet, by considering its orbit in section, or as viewed from a point in the plane of the ecliptic."

"Let us now contemplate it *in plane*, or as viewed from a station above that plane, and projected on it. Suppose, then *S.* to represent the sun, *a. b. c. d.* the orbit of Mercury, and *A. B. C. D.* a part of that of the earth, the direction of the circulation being the same in both, viz., that of the arrow. When the planet



stands at *a.*, let the earth be situated at *A.*, in the direction of a tangent, *a. A.* to its orbit; then it is evident that it will appear at its *greatest elongation* from the sun,—the angle, *a. A. S.*, which measures their apparent interval as seen from *A.*, being then greater than in any other situation of *a.* upon its own circle.

(471.) Now, this angle being known by observation, we are hereby furnished with a ready means of ascertaining, at least approximately, the distance of the planet from the sun, or the radius of its orbit, supposed a circle. For the triangle *S. A. a.* is right-angled at *a.* and consequently we have *S.a.* : *S.A.* : : sin. *S. A. a.* : radius, by which proportion the radii *S. a.*, *S.A.* of the two orbits are directly compared. If the orbits were both exact circles, this would of course be a perfectly rigorous mode of proceeding; but (as is proved by the inequality of the resulting values of *S. a.* obtained at different times) this is not the case; and it becomes necessary to admit an eccentricity of position, and a deviation from the exact circular form in *both* orbits, to account for this difference. Neglecting, however, at present this inequality, a mean or average value of *S.a.* may, at least, be obtained from the frequent repetition of this process in all varieties of situation of the two bodies. The calculations being performed, it is concluded that the mean distance of Mercury from the sun is about 36,000,000 miles; and that of Venus, similarly derived,"

"about 68,000,000; the radius of the earth's orbit being 95,000,000."

We remark that the angle of greatest elongation, given by Lardner, as about 45° or 46°, is estimated by Herschel at about 47°. There is no reference to the difficulty of accurately determining the angle, but Art. 468, which is here quoted for that purpose, will assist in making apparent the disadvantageous circumstances under which the measurement has to be made.

Quotation continued.

Outlines of Astronomy.

Art. (474.) "The circumferences of circles are in the proportion of their radii. If, then, we calculate the circumferences of the orbits of Mercury and Venus, and the earth, and compare them with the times in which their revolutions are performed, we shall find that the actual velocities with which they move in their orbits differ greatly; that of Mercury being about 109,360 miles per hour, of Venus 80,000, and of the earth 68,040. From this it follows that at the inferior conjunction, or at *b*., either planet is moving in the *same* direction as the earth, but with a greater velocity; it will, therefore, leave the earth *behind* it; and the apparent motion of the planet viewed from the earth, will be *as if* the planet stood still, and the earth moved in a contrary direction from what it really does. In this situation, then, the apparent motion of the planet must be contrary to the apparent motion of the sun; and, therefore, retrograde. On the other hand, at the superior conjunction, the real motion of the planet being in the opposite direction to that of the earth, the relative motion will be the same as if the planet stood still, and the earth advanced with their united velocities in its own proper direction. In this situation, then, the apparent motion will be direct. Both these results are in accordance with observed fact."

The Art. last quoted contains, apparently, the expression of a (very deceptive and mischievous) prejudice, which, in adopting the quantities of distance given by Lardner, and the methods by which those quantities are obtained, has been adopted along with them. The prejudice, which we understand to be expressed, is that —when two planets (bodies) are revolving around a common centre, the one being nearer to the centre than the other, if the areal (actual) velocities of the two are equal, the same relative positions of the two will be preserved; or, in other words, that, since both revolve with the same velocity, if both commence the circle of revolution together, both will also terminate the circle together, and will keep in the same line (same direction from the centre) throughout the revolution. No doubt, any one, even far less highly educated than Sir John Herschel, whose mind is brought to the particular consideration of the case, will easily perceive the fallacy arising from confounding the law of angular with that of areal velocity; but it does not follow that a highly educated mind may not entertain and be deceived by such a prejudice. The words (already quoted) are, "Either planet is moving in the *same* direction as the earth, but with a greater velocity; it will therefore leave the earth *behind* it, and the apparent motion of the planet, viewed from the earth, will be *as if* the planet stood still, and the earth moved in a contrary direction from what it really does." The velocity here alluded to, as stated just previously, is the areal velocity, of which the estimated relative proportions are given; the positive statement inferentially includes the negative, viz., that if the areal velocities were equal, the planet would not leave the earth behind it, etc. Now, such an inference is, in fact, quite unsound; for example, suppose the one planet to be at half the distance from the centre, then, if both planets move with equal areal velocity, the one which is at only half the distance from the centre, will move with twice the angular

velocity, and make two revolutions in the interior circle, whilst the other is making one revolution in the exterior; and so, in like manner, will make one complete revolution, whilst the outer planet makes a half revolution, or 20 degrees whilst the other makes 10 degrees; consequently the interior planet, if both start together with equal areal (actual) velocity, will immediately leave the exterior planet behind it.

The observed synodic periods of the other principal planets are Mars 780 days, Jupiter 398 days, Saturn 377.9 days.

From which, assuming the distance of the earth from the sun, as before, at 95 million miles, we obtain the following :—

	Synodic period. Days.	Heliocentric period. Days.	Revolutions of earth to one revolut'n of the planet. (Angular velocity.)	The resulting distance from the sun. Miles.
Venus	584	225	0·6154	58,461,540
Earth	....	365	1·0000	95,000,000
Mars	780	687	1·881	178,965,000
Jupiter...	398	4333	11·860	1126,000,000
Saturn ...	377·9	10759·22	29·480	2800,000,000

We have now to consider the case of an inferior planet as furnishing evidence in respect to the supposed velocity of light. In the semi-periods of the motion of an inferior planet from conjunction to conjunction, as observed from the earth, there must be, if we assume the velocity of light according to the hypothesis, an apparent difference, proportional to the lesser distance, of the same kind as that already pointed out in the case of a superior planet (Jupiter); only that, instead of a difference caused by the distance equal to the diameter of the earth's orbit, the distance will be now equal to the diameter of the

planet's orbit; the first observation being made when the planet is in inferior, and the second, when in superior conjunction. The precise moment of superior conjunction can be ascertained by observing the times of the planet's position when near to and within an equal number of degrees of the sun before and after conjunction respectively. The moment of inferior conjunction may be ascertained in the same manner, but more accurately and directly, in the case of Venus, by observing the transit of the planet across the sun's disc.

These observations being correctly made, there would necessarily be, according to the velocity-of-light hypothesis, a difference in the time of about 10 minutes between the two synodical semi-revolutions; that is the semi-revolution from inferior to superior conjunction would appear to occupy 5 minutes more than half the actual time, and the semi-revolution from superior to inferior conjuction, 5 minutes less than half the actual time of the synodical period.

The supposed facts (of observation) upon which the velocity of light-hypothesis is based, and upon which it is primarily altogether dependent, are three. Of these, the oldest and by far the most important (and which is, indeed, generally looked upon as being alone the fundamental and sure support of the theory), is Rœmer's observations of the eclipses of Jupiter's satellites. We have now shown, with respect to those observations, that the difference in the time, attributed to the velocity of light, is an illusion occasioned by the neglect to take into consideration the variation in the apparent size of the shadow.

The second of the supposed facts is the *aberration of light.* It has been now shown that the reasoning which attributes the phenomena to this cause is unsound, and that the aberration-theory is without actual support of fact. It is therefore unreal.

The third supposed fact is the result of certain experiments with Wheatstone's reflecting apparatus. But the result of these experiments as evidence on the primary question is objectionable, inasmuch as the answer to that primary question, viz., whether light has velocity, was assumed therein; and the actual question which the enquirer proposed thus to submit to experiment, to be answered and determined, was—what is the quantity or amount of the velocity ?* If it be assumed, on the contrary, that light has no velocity, an experiment with an apparatus of this description similarly conducted would, nevertheless, give an apparent velocity as the result, according to the number of reflectors employed; because the light leaves the last reflector subsequently to its leaving the reflector next before it, which, again it leaves subsequently to the one next before that, and so on; and, therefore, in a series of reflectors, a certain time would be occupied proportional to the number of reflectors, but which would not furnish any evidence that time was occupied in the transmission of the light from one reflector to the next.† It is true the result of the experiments with this apparatus is stated to have been in close agreement with the velocity which had been previously attributed to light; but, when we consider that such an agreement, even if the experiments were conducted with

* That is to say, the time might be occupied in the act of reflection, not in the light travelling or moving from the surface of one reflector to the surface of the next.

† In thus stating the question, submitted to experiment, we are, according to our view, extending rather than lessening the significance of the question actually submitted. The question submitted was practically, is that amount of velocity already established exactly correct? The conviction (prejudice) in the minds of those submitting the question being not only that a velocity was established, but that the quantity of velocity had been ascertained either with precision or with a close approximation thereto. In all probability more than a slight discrepancy in the result, from what it was already decided that result must be, would have condemned the apparatus as being in some way unsuitable for the experiment.

scrupulous precaution and care, might be quite fortuitous, and when we consider, also, that the experiments were undertaken with a foregone conclusion or prejudice, of so strong a character that it might be called a conviction, [*i. e.* an unsound conviction], not only as to a velocity but also as to the established quantity of that velocity, we cannot allow that these experiments, viz., with Wheatstone's reflecting apparatus, standing alone and unsupported as they now do, are entitled to be considered as furnishing evidence of value, in any degree, in regard to the primary question.

Since, therefore, it has been now shown that the several theories, which attribute a material nature to light (meaning thereby the influence which occasions light), are, each of them severally, and all of them collectively, unsound and consequently untenable; and since it has been also shown that the supposed facts of observation, by which the velocity attributed to light was considered to be established, are, in that sense, illusory and do not, in fact, support such conclusion, we are thrown back upon the primary question—*is light material?* Now, if light be *material* in its nature, it is certain that *time* must be occupied in its transmission; and, inverting the proposition, if no *time* is occupied in its transmission, then it is certain that light is not of a *material* nature. To answer the question in this form we have the positive evidence of Roemer's observations, confirmed by all later observers, of the eclipses of Jupiter's satellites. This is, perhaps, the only positive (direct) evidence* which can, at the present moment

* There is much *negative* evidence, some of which we have alluded to, or indicated. Theoretical considerations are, we opine, in the present state of knowledge, if the mind be freed from the prejudice occasioned by the undulatory and other theories, altogether opposed to the idea of light having velocity. If, for example, such a supposition be entertained, it immediately appears to follow that an interference and confusion, occasioned by light arriving at the same time from a number of different objects, would necessarily take place.

be put before the reader as a fact demonstrated by direct observation, and as, therefore, indisputable: but it is, we opine, entitled in itself to be considered conclusive; because the distance of the planet Jupiter (even assuming the estimated distance now accepted by astronomers) is so great that, as already stated, any conceivable velocity of a material substance or of an influence transmitted through a material fluid (or any form of matter) would necessarily occupy a very appreciable quantity of time in travelling from that planet to the earth: so that herein we have negative evidence corroborating the positive.

Wherefore we conclude that the evidence *in fact* is sufficient to answer demonstratively the primary question; and the answer to that question is accordingly—that the nature of light (meaning thereby the influence which occasions light) is spiritual, and not material.

Assuming that the conclusion just stated, in regard to the primary question, is sound; let us now see what secondary conclusions of an important character will follow as corollaries or consequents thereto.

For this purpose it will be convenient to take physical science, or that division of physical science, to which the phenomena of light and sound belong, and to put these conclusions in the form of a brief generalization, making use of such of the recorded facts, and a part of such of the common knowledge belonging to the subject, as may be considered to be certified by science at the present time.

The Physical Forces of Natural Science.

Force is that which causes a change in the condition of matter, overcoming a resistance (antagonism or opposition); which *resistance* is equal in amount to the *quantity* of *force* exerted.

Force is known to us as manifested in several forms or conditions (or modes), differing from each other and having its active energy in each condition controlled by definite and distinct laws, which have been more or less investigated and are in some measure known to us.

The several forms or modes of force, now known to us, as acting on the material world, and distinguished each from each by the definite and different effects on matter of its manifestations in the one particular form from those in each of the other forms, are - - - -

MANIFESTATION OF FORCE ON MOLECULAR MATTER.

Force	Electric Force.	Volumetric, (Frictional) Electricity.
	Motive Force.	Light—or (Luminiferous-force.)
	Attractive or Gravitative Force.	Heat—or (Caloric-force.)
		Molecular (Voltaic) Electricity.
		Sound—(Acoustic force.)

MANIFESTATION OF FORCE ON AGGREGATED MATTER.

Force	Motive Force.	Motion of material bodies. Mechanical effect.
	Gravitative Force.	Mechanical effect. Weight or Gravity.

All *change* in the material world is the result of a *manifestation* of *force*. The primary or general law under which all the forms or conditions (modes) of force are manifested and become cognizable by us is that of *succession*.

The *successive manifestations* of *force*, that is, its measurement by the successive effects of its manifestations on matter is known to us as *time*. *

Distance is the recognized, collective expression for the result of a (certain) definite number of the successive effects of the manifestations (on matter) of motive force-energy.

Force is, therefore, not *material* but *spiritual*. Since the cognition of the material world (*i.e.*, of matter) by the spiritual being, is in ourselves a manifestation or result of *force-energy* acting on *matter*, we cannot divest ourselves of the *idea* of *time* in cognizing matter except in the case of a *simple sensation*, because the successive recognitions of the successive effects is that which we mean by the expression 'idea of time.'

But *matter* itself, in its simple elementary condition, separated from force, is only indirectly known to us. Chemical science teaches us to indirectly recognise the fact that such simple elementary matter is existent†, but it has not been, neither can it be, directly cognized by us apart from its spiritual adjunct *force*.

Therefore all the forms or varieties of compound matter known to us, are compounded of (*the spiritual and the material*) force together with (compound) matter.

And, also, by an addition to or a deduction from the quantity of *force* contained in a particular form (variety)

* This may be familiarly illustrated by reference to the dial-plate of a clock, where the motion of the hour-hand measures the successive vibrations of the pendulum. The measurement may be read off (cognized) in hours, minutes, or seconds, but it is always a measurement from a definite starting point (zero-point), and it expresses the collective cognition of the successive vibrations which have taken place subsequent to that point.

† *But to assume that* chemical evidence, as set forth in the atomic theory, makes us acquainted with simple elementary matter separated from *force* is, perhaps, to assume (*i.e.*, to include the assumption) that matter itself is primarily a materialized (fixed) condition or mode of (gravitative) force.

of matter, the physical condition of that form of (compound) matter may undergo a change..although its essential form as distinguished from other forms of (compounded) matter remains unaltered: ... as, for example, water, which by the addition or deduction of that form of force known as *heat*, assumes accordingly the condition of *steam* or of *ice*, in either of which conditions it still remains essentially the same form or variety of (compound) matter—viz., *water*, as distinguished from all other varieties of matter.

Force in combination with matter may be considered dormant (*latent*); the energy of the force may be said to be employed (in resisting change) in preserving the existence, condition, and form of the compounded matter; it has been (so to speak) *materialized*, and has become (temporarily) a part of the compound matter; but, if the equilibrium of the compounding elements of the body be disturbed by addition or interference of (other) *force*, the condition, or, it may be, the compounded form, of the body must undergo modification or decomposition, and a certain quantity, exactly proportional to the quantity of matter acted upon and changed, of force is set free to manifest its energy as active force, by combining with, or disturbing the conditions of, other forms of matter.

Herein we have particular sources of *force* or of manifestations of force-energy within the material world, as known to us. It may be said that the source of all the force-energy (usually) recognized by us as belonging to the material world is such a disturbance of existing compounds or combinations, and the consequent setting free of force previously latent or inactive, (so to speak,) in the compound. Sidereal (solar) force may be, however considered, as, to some extent, a possible exception*

* If it be assumed that the aggregate quantity of compound matter in the universe undergoes increase *i.e.*, that a manifestation of

i.e., as, possibly, an outside source; because, although there is a strong probability that the active or free force thence derived is the result only of a continuous regulated (material) disturbance of the same character, and that the sun may be correctly understood to act as a reservoir of force, continually collecting and redistributing a regulated supply—nevertheless we cannot be quite sure, in the present state of knowledge, that sidereal (solar) force may not include a more distinct manifestation of outside † spiritual energy, in which case solar force would have have to be looked upon as the primary source of terrestrial force; whereas, otherwise, *i.e.*, assuming the sun to be the central recipient and distributor of active force—terrestrial (or planetary) and solar manifestations of force must be looked upon equally as parts of that collective quantity of force belonging to the solar system.

Creative energy is continually or occasionally taking place) a proportionate addition to the collective quantity of force would be, perhaps, necessary, and (it is meant that) the sun, or other central star, may possibly be the *directly* or *immediately* primary source of the additional quantity.

* That is—primary, in a merely terrestrial sense.

† Meaning thereby . . . a source outside that which is known to us as the material universe.

THE RECORD OF PHYSICAL FACTS.

A reference to the record of observed facts will show the close relationship of volumetric (frictional) electricity and light.

(*Note.*—It is necessary to remark that certain theories or assumptions have been allowed in some cases to mingle with the recorded facts in such wise as to necessitate considerable caution; for example, the theory or assumption of two electricities, or two kinds (varieties) of electricity, having characteristic properties, in some respects directly opposite in the one kind from the corresponding characteristic properties in the other. It was early objected to such assumption that it was superfluous and undemonstrated (unsupported), and a sort of compromise was effected in regard to the nomenclature, by calling the (supposed) one kind *positive*, and the other *negative* electricity. Since that time, however, the illegitimate influence of theory has been allowed still further to usurp the legitimate authority of science, and it seems to be now almost forgotten that the two electricities, or two kinds of electricity, is a mere hypothesis unsupported excepting by a certain superficial appearance of probability which would equally apply to a supposition of 'coldness' being a variety or form of 'heat'; that is to say, to an assumption of two 'heats' or two kinds (varieties of heat), in which certain of the characteristic properties of the one would be the opposite to the corresponding characteristics of the other.)

Volumetric Electricity and Light.

Encyclopedia Britannica.

Art. *Electricity. Part* 1. Sect. V.—*On the Electric Spark.*

"Since the discovery of electric light by Otto Guerick and Dr. Wall, the subject has attracted the particular attention of philosophers. In exciting a glass tube, or

in working an electrical machine in the dark, sparks and streams of light are distinctly visible; but the phenomenon is best seen when the knuckles or a brass ball is brought near to an electric conductor. A bright light, called the electric spark, passes from the conductor to the knuckle or ball, and exhibits a great variety of phenomena, varying with the nature and intensity of the electricity, and with the form, magnitude, distance and nature of the bodies between which it passes.

The electric spark is produced by the action of the positive electricity in the conductor upon the neutral electricity in the knuckle or ball that receives the spark, the former decomposing the latter. When the attraction between the two electricities is sufficiently powerful to overcome the resistance of the air, the two fluids on the knuckle recombine with a noise, accompanied by a brilliant spark like the forked lightning in a thunderstorm. This mode of discharging the electricity of conductors is called the *disruptive discharge*, and the distance of the bodies between which it is made is called the *striking distance*.

Exp. 1. Having screwed into a prime conductor a brass ball about two inches in diameter, and projecting about three inches, electrify the conductor positively, and hold another ball near the first. Long ramified zig-zag sparks will pass between the two balls, as shown in Fig. 6, (Pl. 10,) where *pos.* is the positively electrified ball, and *nat.* the one held in the hand in a natural state of electricity. If the ball on the conductor is very small, the spark will become a faint divided brush of light. If the ball on the conductor is electrified negatively, the spark will be as shown in Fig. 7, (Pl. 10,) clear, straight, and more luminous. If one of the balls is positively, and the other negatively electrified, the forms shown in Fig. 6, and 7, will be combined as in Fig. 8. When, in this last experiment, the distance of the balls is not too great, the positive zig-zag spark will strike

the negative straight spark about one-third of the length of the latter from its point, the other two-thirds becoming very luminous. Sometimes the positive spark strikes the negative ball at a distance from the negative spark.

Exp. 2. If two conductors *P. M.*, Fig. 9, three-fourths of an inch in diameter, and having spherical ends, are placed parallel to each other, at the distance of two inches, so as to have their ends pointing in different directions six or eight inches asunder; then, if *P.* is positively electrified, its spark will strike the other conductor *M.* in its natural state as in Fig. 9. If *M.* is electrified negatively, and *P.* connected with the earth, the conductor *M.* will send the negative spark to *P.* as in Fig. 10; and if the conductors have opposite electricities the positive spark will appear at one end and the negative at the other, as shown in Fig. 11.

Exp. 3. Upon the brass stem *b. c.*, Fig. 12; having a fine point at *c.*, place a brass ball *A.*, about three inches radius, so that the point *c.* can be protruded to any distance beyond the ball, or be drawn within it, as shown in the figure. In this last state the point produces no effect, and the zigzag spark appears between the balls. In proportion, however, as the point is protruded, its transmitting power is increased, and it may be made to have the same effect as any ball from the smallest size to one three inches radius. When the point projects to a particular distance, it acts as if no ball were present.

Exp. 4. Hold an insulated sheet of paper at a small distance from a positively electrified conductor, and a beautiful star with distinct radiations will be thrown upon the paper. If the conductor is negatively electrical, a cone of rays, with its base on the paper and its apex on the conductor, will replace the star.

Exp. 5. If the point of a needle is presented to a positively electrified conductor in the dark, the point will be illuminated with a star; but if the conductor is

negative, the needle will exhibit a pencil or brush of light.*

The following experiment illustrates the effect of distance on the spark.

Exp. 6. Fix a sharp-pointed wire to the end of the prime conductor, and having electrified it positively, hold an insulated ball of metal very near the metallic point; a succession of small and *brilliantly white* sparks will pass between them. The white colour will tend to red as the distance of the ball and the point is increased, and at a certain distance the sharp explosions will cease, and a feeble violet light will diverge from the extremity of the point, covering with its base the nearest half of the sphere.

The influence of the form of the body upon the spark which it gives is considerable. Professor Hildebrand, of Erlang, found an obtuse cone with an angle of 52° gave a much more luminous spark than one with an angle of 36°, and he found that the parabolic rounding of the summit, or slight inequalities of the surface, are particularly advantageous in the production of a strong light. The influence of points on the spark has been already described. The nature of the body by which the spark is taken exercises also an influence upon its magnitude and its colour. Professor Hildebrand made some interesting experiments on this subject. The pieces of metal had a conical form, and of the same shape and size. When they were fixed in the same manner at the end of an insulated conductor, the sparks which they yielded differed much in extent. The following table exhibits the results of these experiments, the metals at the head giving the greatest sparks:—

Regulus of Antimony,	Sulphuret of Copper,	Lead.
Gold	Tin	Steel.
Silver	Zinc	do., tempered.
Brass	Iron	" "

*The results of these two experiments (4 and 5) are opposed to the theory of two distinct kinds of volumetric electricity?

PLATE 10.

Fig. 13.

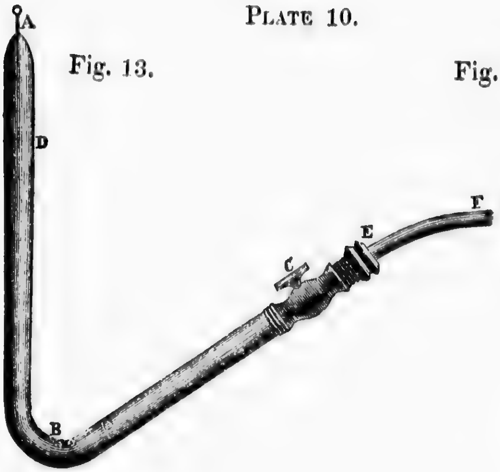
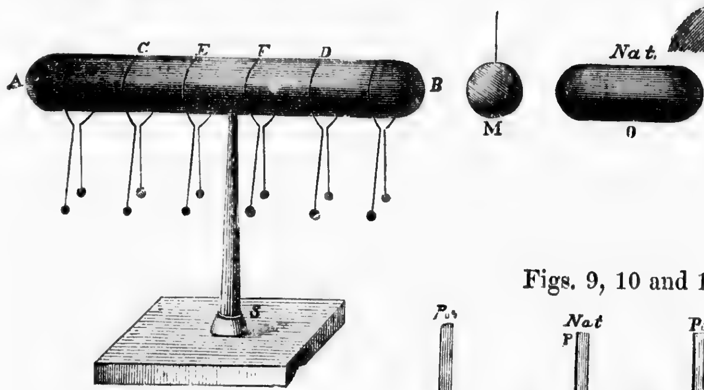
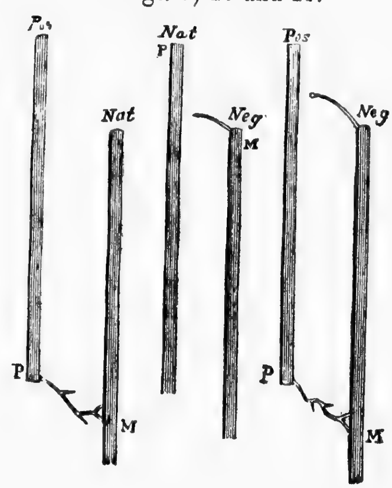


Fig. 12.

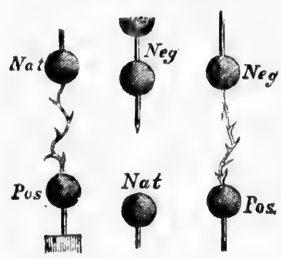
Fig. 1.



Figs. 9, 10 and 11.



Figs. 6, 7 and 8.



When the spark is *white* by taking it with a metallic body, it will, under the same circumstances, be *violet* if taken with the finger. If the spark is taken with ice or water, or a green plant, its light will be red; and if it is taken with an imperfect conductor, such as wood, the light will be emitted in faint streams.

The medium through which the spark is transmitted exercises also a remarkable influence on its colour and form. A spark capable of passing through only half an inch in common air, will pervade six inches of the Torricellian vacuum. The apparatus used by Sir H. Davy for examining the influence of a vacuum, &c., is shown in Fig. 13, where *A.B.C.* is a bent glass tube, *A.* the wire for communicating electricity, *D.* the surface of the quick-silver or fused tin for producing a vacuum, *B.* the tube to be exhausted by the stop-cock *C.* after being filled by means of the same stop-cock when necessary with hydrogen, and *E. F.* the moveable tube connected with the air-pump. Sir H. Davy found, that in all cases when the mercurial vacuum was perfect, it was permeable to electricity, and rendered luminous either by the common spark or the charge of a Leyden jar. The intensity of these phenomena varied with the temperature. When the tube *A.B.C.* was very hot, the electric light appeared on the vapour of the mercurial vacuum of a bright green colour, and of great density. As the temperature diminished it lost its vividness. At 20° below zero of Fahrenheit it was perceptible only in considerable darkness. When the minutest quantity of rare air was introduced into the mercurial vacuum, the colour of the electric light changed from *green* to *sea green*, and by increasing the quantity, to *blue* and *purple*. At a low temperature the vacuum became a much better conductor. A vacuum above fused tin exhibited nearly the same phenomena. At temperatures below zero the light was yellow, and of the palest phosphorescent kind, just visible in great darkness, and not increased by heat.

When the vacuum was formed by pure olive oil, and by chloride of antimony, the electric light through the vapour of the chloride was more brilliant than that through the vapour of the oil; and in the last it was more brilliant than in the vapour of mercury at common temperature. The light was of a *pure white* with the chloride, and of a *red* inclining to *purple* in the oil.

Upon rarefying the air five hundred times in a glass vessel a foot long and eight inches in diameter, Mr. Smeaton made the vessel revolve rapidly on a lathe, at the same time exciting it with the palm of his hand. A large quantity of lambent flame appeared under his hand, *variegated with all the colours of the rainbow.* Though the light was steady, every part of it was continually changing colours.

In carbonic acid gas the light of the spark is white and brilliant, and in hydrogen gas it is red and faint. When the sparks are made to pass through balls of wood or ivory they are of a *crimson* colour. They are *yellow* when taken over powdered charcoal, green over the surface of silvered leather, and purple from imperfect conductors.

The following experiments on the spark and electrical light are both instructive and entertaining.

Exp. 1.—Cover a metallic wire with silk, and form it into a close flat spiral of not more than twenty-four revolutions, with the different coils in contact. When a considerable electric charge (of about two square feet of coated surface) is passed through it, a vivid light resembling that of an artificial fire-work will be seen, even in daylight, originating in the centre of the spines.

Exp. 5. The *luminous jar*—shown in Fig. 16—is a still more beautiful experiment. In one which is now before us, fifty-five squares of tin foil an inch square, and each perforated with a hole four-tenths of an inch in diameter, are pasted in five rows on the outside and

inside of a glass jar *A.B.*, Fig. 16, about 5 inches in diameter and 11 inches high. The diagonals of the square pieces are placed horizontal and vertical, and their points or angles are separated by about one-twelfth of an inch. The rows of the tin-foil squares are similarly placed on the inside of the jar, with this difference only, that their horizontal points nearly touch one another at the centres of the circular holes of the outer squares. The brass ball *A.* communicates with the inside squares by a wire, and when it is charged by the prime conductor, a hundred and ten sparks will be seen at once in a horizontal, and a hundred and ten in a vertical, direction when the jar is discharged.

Fig. 16.

Exp. 6.—Take a glass cylinder three inches wide and three feet long, so fitted up that a brass plate may be let down from the top of the cylinder, so as to stand at any distance from another brass plate fixed at the bottom of the cylinder. When the cylinder is exhausted of air in the usual manner, and the upper plate communicates with the prime conductor, and the lower one with the ground, a brilliant sheet of light will pass from the upper to the lower plate. If the distance of the plate is ten inches, and if the charge of a Leyden jar is made to pass from the one to the other, a continuous body of the most brilliant fire will pass between them."

For the purpose of verifying and amplifying the foregoing examples we will now take...

Lardner's Natural Philosophy.

Chap. XI.—Luminous Effects of Electricity.

(1810.) "*Electric fluid not luminous.*—The electric fluid

is not luminous.* An insulated conductor, or a Leyden jar or battery, however strongly charged, is never luminous so long as the electric equilibrium is maintained and the fluid continues in repose. But if this equilibrium be disturbed, and the fluid move from one conductor to another, such motion is, under certain conditions, attended with luminous phenomena."

(1811.) "*Conditions under which Light is developed by an Electric Current.*—One of the conditions necessary to the development of light by the motion of the electric fluid is, that the electricity should have a certain intensity. If the conductor of an ordinary electric machine while in operation be connected with the ground by a thick metallic wire, the current of the fluid which flows along the wire to the ground will not be sensibly luminous; but if the machine be one of great power, such for example as the Taylerian machine of Haarlem, an iron wire 60 or 70 feet long communicating with the ground and conducting the current will be surrounded by a brilliant light. The intensity of the electricity necessary to produce this effect depends altogether on the properties of the medium in which the fluid moves. Sometimes electricity of feeble intensity produces a strong luminous effect, while in other cases electricity of the greatest intensity developes no sensible degree of light.

"It has been already explained that the electric fluid with which an insulated conductor is charged is retained upon it only by the presence of the surrounding air. According as this pressure is increased or diminished, the force necessary to enable the electricity to escape will be increased or diminished, and in the same proportion.

When a conductor, *B.*, in communication with the

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* This statement appears to be contradicted instead of supported by what immediately follows.

ground, approaches an insulated conductor *A.* charged with electricity, the natural electricity of *B.* will be decomposed, the fluid of the same name as that which changes *A.* escaping to the earth, and the fluid of the opposite name accumulating on the side of *B.* next to *A.* At the same time, according to what has been explained (1785), the fluid on *A.* accumulates on the side next to *B.* These two *tides* of electricity of opposite kinds exert a reciprocal attraction, and nothing prevents them from rushing together and coalescing, except the pressure of the intervening air. They will coalesce, therefore, so soon as their mutual attraction is so much increased as to exceed the pressure of the air.

This increase of mutual attraction may be produced by several causes. *First,* by increasing the charge of electricity upon the conductor *A.*, for the pressure of the fluid will be proportional to its depth or density.* *Secondly,* by diminishing the distance between *A.* and *B.*,

* Herein may be remarked the (perhaps unintentional) expression of a conclusion or prejudice to the effect that the electric influence (force) is a material fluid, and consists of particles which gravitate. If this be not the intended meaning . . . why not have written 'proportional to the quantity'? Some writers on electricity thus use the term 'fluid' (electric-fluid) with a sort of protest that they are not to be understood as defining or denoting the character of the influence. They nevertheless use it; and every one is familiarised with the idea of an electric-*fluid* passing or *flowing* in *a current* through a conductor. Thus we have an illustration of some of the consequences of introducing definitions into scientific nomenclature based on vague conjecture. The supposition of the *two* electricities will not, we opine, be found to be supported by fact; yet it is not, in the existing state of scientific knowledge, unreasonable, and may be considered, for the moment at least, tenable, and therefore a scientific theory. The assumption of that theory is the existence of two electricities—that is, of two positive electricities having certain different and opposite characteristics; and one of these two positive electricities is called negative electricity. The other case (the misuse of the term 'fluid' is, however, much more seriously objectionable; and the supposition therein embodied, if formerly considered to belong to science, has become long since untenable, being contradicted by many of the now well-known facts pertaining to the subject.

for the attraction increases in the same ratio as the square of that distance is diminished; and, *thirdly*, by increasing the conducting power of either or both of the bodies *A.* and *B.*, for by that means the electric fluids, being more free to move upon them, will accumulate in greater quantity on the sides of *A.* and *B.* which are presented towards each other. *Fourthly*, by the form of the bodies *A.* and *B.*, for according to what has been already explained (1776), the fluids will accumulate on the sides presented to each other in greater or less quantity, according as the form of those sides approaches to that of an edge, a corner, or a point.

When the force excited by the fluids surpasses the sustaining force of the intervening air, they force their passage through the air, and, rushing towards each other, combine. This movement is attended with light and sound. A light appears to be produced between the points of the two bodies *A.* and *B.*, which has been called the *electric spark*, and this luminous phenomenon is accompanied by a sharp sound like the crack of a whip."

(1812.) "*The Electric Spark.*—The luminous phenomenon called the electric spark does not consist, as the

Fig. 11.

name would imply, of a luminous point which moves from the one body to the other. Strictly speaking, the light manifests no progressive motion. It consists of a *thread of light*, which for an instant seems to connect the two bodies, and in general is not extended between them in one straight unbroken direction, like a thread which might be stretched tight between them, but has a zigzag form resembling more or less the appearance of lightning.

(1813.) "*Electric aigrette.*—If the part of either of the bodies *A.* or *B.* which is presented to the other have the form of a point, the electric fluid will escape, not in the form of a spark, but as an aigrette or brush light, the diverging rays of which sometimes have the length of two or three inches. A very feeble charge is sufficient to cause the escape of the fluid when the body has this form."

(1814.) "*The length of the spark.*—If the knuckle of the finger or a metallic ball at the end of a rod held in the hand be presented to the prime conductor of a machine in operation, a spark will be produced, the length of which will vary with the power of the machine. By the *length of the spark* must be understood the greatest distance at which the spark can be transmitted. A very powerful machine will so charge its prime conductor that sparks may be taken from it at the distance of 30 inches."

(1815.) "*Discontinuous conductors produce luminous effects.*—Since the passage of the electricity produces light wherever the metallic continuity, or, more generally, wherever the continuity of the conducting material is interrupted, these luminous effects may be multiplied by so arranging the conductors that there shall be interruptions of continuity arranged in any regular or desired manner."

(1816.) "*Experimental illustration.*—If a number of metallic beads be strung upon a thread of silk, each bead being separated from the adjacent one by a knot on the silk so as to break the contact, a current of electricity sent through them will produce a series of sparks, a separate spark being produced between every two successive beads. By placing one end of such a string of beads in contact with the conductors of the machine, and the other end in metallic communication with the ground, a chain of sparks can be maintained so long as the machine is worked."

(1817.) "*Effect of rarefied air.*—When the electric fluid passes through air, the brilliancy and colour of the light evolved depends on the density of the air. In rarefied air the light is more diffused and less intense, and acquires a reddish or violet colour. Its colour, however, is affected, as has been just stated, by the nature of the conductors between which the current flows. When it issues from gold the light is green, from silver red, and from tin or zinc white, from water yellow inclining to orange.

Fig. 12.

It is evident that these phenomena supply the means of producing electrical apparatus by which an infinite variety of beautiful and striking luminous effects may be produced. When the electricity escapes from a metallic point in the dark, it forms an aigrette, Fig. 12, which will continue to be visible so long as the machine is worked.

The luminous effect of electricity on rarefied air is exhibited by an apparatus, Fig. 13, consisting of a glass receiver, *b.b.*', which can be screwed upon the plate of an air-pump and partially exhausted. The electric current passes between two metallic balls attached to rods, which slide in air-tight collars in the covers of the receiver *b.b.*'

Fig. 13.

It is observed that the aigrettes formed by the negative fluid are never as long or as divergent as those formed by the positive fluid, an effect which is worthy of attention as indicating a distinctive character of the two fluids."*

* Yes; if we suppose two distinct kinds of electricity; but, if there be only one, the explanation may be thus stated:—(1.) The electricity entering at *b.*', diverges from that ball. (2.) The electricity having been removed from the ball at *b.*', an equivalent quantity is attracted or gravitates thereto.

(1818.) "*Experimental imitation of the auroral light.*—This phenomenon may be exhibited in a still more remarkable manner by using, instead of the receiver *b.b.'*, a glass tube two or three inches in diameter, and about thirty inches in length. In this case a pointed wire being fixed to the interior of each of the caps, one is screwed upon the plate of the air-pump, while the external knobs of the other is connected by a metallic chain with the prime conductor of the electrical machine. When the machine is worked in the dark, a succession of luminous phenomena will be produced in the tube, which bear so close a resemblance to the aurora borealis as to suggest the most probable origin of that meteor. When the exhaustion of the tube is nearly perfect, the whole length of the tube will exhibit a violet red light. If a small quantity of air be admitted, luminous flashes will be seen to issue from the two points attached to the caps. As more and more air is admitted, the flashes of light, which glide in a serpentine form down the interior of the tube, will become more thin and white, until at last the electricity will cease to be diffused through the column of air, and will appear as a glimmering light at the two points."

(1819.) "*Phosphorescent effect of the spark.*—The electric spark leaves upon certain imperfect conductors a trace which continues to be luminous for several seconds, and sometimes even so long as a minute after the discharge of the spark. The colour of this species of phosphorescence varies with the substances on which it is produced. Thus white chalk produces an orange light. With rock crystal the light first red turns afterwards white. Sulphate of baryta, amber and loaf sugar render the light green, and calcined oyster-shell gives all the prismatic colours."

(1822.) "*Electric light above the barometric column.*—The electric light is developed in every form of elastic fluid and vapour when its density is very inconsiderable. A remarkable example of this is presented in the common"

" barometer. When the mercurial column is agitated so as to oscillate in the tube, the space in the tube above the column becomes luminous, and is visibly so in the dark.* This phenomenon is caused by the effect of the electricity developed by the friction of the mercury and the glass upon the atmosphere of mercurial vapor which fills the space above the column in the tube."

Fig. 14.

(1823.) " *Cavendish's electric barometer.*—The electric barometer of Cavendish, Fig. 14, illustrates this in a striking manner. Two barometers are connected at the top by a curved tube, so that the spaces above the two columns communicate with each other. When the instrument is agitated so as to make the columns oscillate, electric light appears in the curved tube." *

(1824.) "*Luminous effects produced by imperfect conductors.*—The electric spark or charge transmitted by means of the universal discharger and Leyden jar or battery through various imperfect conductors produces luminous effects which are instructive.

Place a small melon, citron, apple, or any similar fruit on the stand of the discharger; arrange the wires so that their ends are not far asunder, and the moment when the jar is discharged the fruit becomes transparent and luminous. One or more eggs may be treated in the same manner if a small wooden ledge be so contrived that their ends may just touch, and the spark can be sent through them all. Send a charge through a lump of pipe-clay, a stick of brimstone, or a glass of water,"

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* We would note this experiment as particularly valuable on the assumption that herein we have the conversion of one form of electric force...namely, motion or mechanical effect, into another form... namely, light.

"or any coloured liquid, and the entire mass of substance will for a short time be rendered luminous. As the phosphorescent appearance induced is by no means powerful, it will be necessary that these experiments should be performed in a dark room, and, indeed, the effect of the other luminous electrical phenomena will be heightened by darkening the room."

(1827.) "*Cracking noise attending electric spark.*—The sound produced by the electric discharge is obviously explained by the sudden displacement of the particles of the air, or other medium through which the electric fluid passes."

(NOTE.—It will be understood that we do not consider the undulatory theory of sound to be longer tenable. It does not, however, follow, because air is not the cause or origin of sound, that, therefore, air does not conduct sound; on the contrary, the evidence, we opine, is conclusive that air does conduct sound . . . that is to say, conducts that form of *Force* which occasions the effect called sound.)

THE LUMINOUS TRAIN OF THE COMET.

Returning now to the required explanation as to the luminous train of the comet, (see conclusion of supplement C.), let us again state the actual circumstances such as we found reason, from the previous examination of the case, to believe them to be . . . namely, circumstances more or less similar in character to those of the primary condition of the earth. (Supplement C., page 12.) "The spherical mass of matter in a liquid (molten or fluid) state, occupying the central part of the body, covered by the solid crust in an intensely heated condition, and surrounded by the vaporous and gaseous envelope, would give the appearance of the 'nucleus' and the 'coma.' Now, if we suppose a quantity of free electricity (*i.e.*, uncombined electric-force in the form of

volumetric electricity), belonging to the cometary-mass of matter, to be in a state of disturbance, it is evident from what has been put before the reader that herein we should have *a cause* of *a* luminous appearance. Are the circumstances, such as we have stated, favourable to such supposition? Certainly, they are very favourable; because, since free electricity is readily convertible into that form of electric-force called 'heat,' as, for example, when an imperfect conductor such as a wire is heated and fused by electricity, so is free (active) heat readily convertible into free electricity. It is also apparent that the circumstances known to be favourable to the production of free electricity in the earth's atmosphere...namely, a high temperature of the earth, and a vaporous condition of the air, would be, in the case supposed, far more effective, in consequence of the very high temperature of the solid matter of the comet and the highly vaporous condition of the comet's atmosphere. What would be the probable effect of the sun's influence on a planetary mass (*i.e.*, a comet) in such condition? We shall now show by reference to the observed facts that the probable effect would be to drive the free electricity to that side of the comet opposite to the sun, where it would accumulate, and by which accumulation of electricity, supposing the quantity of it to be very great, the observed appearances of the luminous train would be produced."

For the record of the observed facts we will refer to the same two writers as before.

ELECTRICAL INDUCTION.

Encyclopedia Britannica,* Chap. 1, Sec. XII. — "*On Electrical Induction, or the decomposition of the combined Electricities by actions at a distance.*—In the preceding sections we have considered the phenomena of electricity as produced by friction, and as communicated or transmitted by conductors to other bodies. But it has been "

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* Sir David Brewster.

" found that electricity may be developed in bodies by the mere influence of an electrified body placed at a distance, and we shall now proceed to investigate the laws which regulate this interesting class of phenomena.

Let *A. B.*, Fig. 1 (Pl. 10,) be a cylindrical conductor supported horizontally upon an insulating stand *S.* and having hemispherical ends at *A.* and *B.* Suspend from the points *A. B. C. D. E. F.*, similar pairs of pith balls attached to wires or linen threads, and having insulated it carefully by the stand *S.* touch it with the finger in order to see that it contains no free electricity. Let an electrified sphere *M.* be now brought near it, so that *A. B. M.* are in the same straight line, and that no spark can pass from *M.* to *B.* When this has been done, it will be observed that the pith balls diverge as in the figure, the divergency being a maximum at *A.* and *B.* and equal at these points, becoming less at *C.* and *D.* where it is also equal, and still less at *E.* and *F.*, where the equality of divergence still exists. Between *E.* and *F.* there will be found some *neutral point* where the pith balls exhibit no divergence, and this point will shift its position according to the distances of the electrified body *M.* If we now suspend an unelectrified pith ball by a silk thread, and bring it near to different parts of the cylindrical conductor, we shall find that it is attracted to it in all places except the *neutral point* between *E.* and *F.*

This *neutral point* is never found in the exact middle of the cylinder between *E.* and *F.* Its position varies with the distance of the body *M.* and with the intensity of its charge. In every case, however, it is nearer to the extremity *B.*, next the sphere *M.*, than the distant extremity *A.*

From these experiments we are led to the important and curious results, that an *unelectrified body may be electrified by the influence of an electrified body acting upon it at a distance.* The electricity is in this case said to be *induced*, and the phenomenon is called *electrical induction.*"

"If we now electrify the pith ball which was suspended by a silken thread, and bring it near to the cylinder *A. B.*, we shall find that it is *attracted* by one half of the cylinder, from *A.* for example, to the neutral point between *E.* and *F.*, and *repelled* by the other half from *B.* to the same neutral point.

From this experiment we infer that *the electricity on one half of the cylinder, from one extremity to the neutral point, is Positive, while the electricity in the other half is Negative.**

Bring the electrified pith ball near the electrified body *M.*, and it will be found that, if it was formerly repelled from *A.* it will be attracted by *M.* and *vice versa;* so that we conclude that *the electricity induced upon the half of the cylinders nearest the electrified body is always opposite to that of the electrified body.*

If we now measure the electricity of the body *M.* both before and after the preceding experiments, and make allowance for the dissipation of it through the agency of the adjacent air, we shall find that no part of its electricity has been communicated to the cylinder *A. B.;* and if, while the cylinder *A. B.* is electrified by the inductive influence of *M.*, we either remove *M.* to a distance, or discharge its electricity by touching it with the finger, the electricity of the cylinder *A. B.* will instantly disappear. In like manner, *A. B.* will recover its electrical state the moment that *M.* is brought near it.

Hence it follows that *the positive and negative electricities developed in a conducting body are not communicated to it by that body, but have existed in a state of combination in the substance of the conductor, and have only been separated from their state of combination by the action of the electrified body.*

As the intensity of the positive electricity, as well as its quantity, is the same in one half of the conductor as"

* The inference is, however, based on the hypothesis of the existence of two distinct electricities, or kinds of electricity.

" that of the *negative* electricity is in the other half, and as there is no remaining or free electricity in the cylinder *A. B.* when the body *M.* is withdrawn, it follows that the union or recombination of the two electricities has neutralized or saturated each other. But as the two united electricities have not been destroyed by their union, they exist in a new state which is called the *natural electricity* of bodies. The electricity, therefore, which thus naturally resides in conductors, consists of equal quantities of *positive* and *negative* electricity, which neutralize each other's action, and are consequently incapable of producing any of the phenomena of free electricity, or of a portion of positive or negative electricity existing in a separate state.

With these explanations, we are now able to understand how the cylinder *A. B.* is electrified by the influence of the electrified body *M.* We have closely proved, by direct experiment, that bodies similarly electrified repel each other; and we have shown in Section X. that this repulsion and attraction does not take place between the material particles of the bodies, but between their electricities, or the electric fluids which they respectively contain. Hence we may enunciate the law in the following manner:—*Similar electricities repel each other, and dissimilar electricities attract each other.* Now, when the sphere *M.*, which we shall suppose to be electrified positively, is brought near the cylinder *A. B.*, in which the electricity exists in its natural or combined state, it will repel all the *positive* electricity, and attract all the *negative* electricity, overcoming the tendency which each has to diffuse itself in virtue of the mutual repulsion of its own particles, and the tendency which the two opposite electricities have to re-combine by their mutual attraction. Hence all the *negative* electricity will be *attracted* to and occupy the half *F. B.* of the cylinder, and all the *positive* electricity will be *repelled*, and occupy the remoter half *E. A.* If *M.* is negatively electrified, the"

"opposite effects will be produced. Let the body *M.* be now withdrawn, the repulsive and attractive forces which it exercised upon the natural electricity of *A. B.* will cease, and the two electricities, separated by its action, will re-combine by their mutual attraction, as well as by the mutual repulsion of the particles of each, and the cylinder *A. B.* will be restored to its natural state of electricity.

The principle of electrical induction which we have now illustrated enables us to give a satisfactory explanation of the phenomena of attraction which have been described in Section II. It was there shown that electrified bodies attracted light and unelectrified bodies that were brought near them; but it will now appear that these apparently unelectrified bodies were first electrified by induction, and, in consequence of the decomposition of their natural electricities, were attracted by the excited body. Thus if *M.* (Fig. 1) is an electrified body placed in a perfect vacuum, and *A. B.* a small light body suspended near *M.*, and capable of moving toward it, then *A. B.* will be so electrified by the influence of *M.* that the electricity of the same name as that of *M.* will be accumulated in the half *F. B.* of the cylinder, and the other electricity in the half *E. A.* But the electricity of *M.* attracts that of *B. F.* more powerfully than it repels that of *E. A.*, and consequently the light body *A. B.* will be attracted to *M.* in consequence of the previous decomposition of its native electricity. If this decomposition cannot be effected by *M.*, or if it takes place with difficulty, the body *A. B.* will not be attracted, or will be attracted less readily."

M. Biot has illustrated this position by the following simple experiment: "Suspend by fine silk threads two small balls of equal dimensions, one of them being made of pure gum-lac, and the other of gum-lac either gilt on its surface or covered with a thin plate of tin foil. When these two balls are placed beside each other, and at a"

"small distance, bring near them an electrified tube of glass or sealing-wax, and it will be seen that the gilt ball will be more strongly and easily attracted than the other. The uncoated ball of lac will not begin to be attracted till after a certain time, when the decomposition of its natural electricity has been effected; and thus its electrical state will continue after the removal of the electrical body."

"In examining the action of *M.* upon *A. B.* (Fig. 1,) we supposed that no change took place in the electrical condition of *M.*; but this is not the case, for the body *A. B.* as soon as its natural electricity has been decomposed, begins to react upon *M.* through the agency of its separated electricities. These separated electricities not only tend by their attractive and repulsive forces to change the distribution of the free electricity which exists in *M.*, but also to decompose its natural electricity, and thus to increase its free electricity by one of the two separated electricities. When this change has been effected upon the electrical state of *M.*, its action upon *A. B.* will also change. It will decompose a new quantity of the natural electricity of *A. B.* and distribute the positive and negative electricities of which it is composed in the halves *A. E.*, *B. F.*; and these new portions will again react upon *M.* till a permanent equilibrium is effected among all the attractive and repulsive forces which are thus brought into play." * * *

"If we connect *A. B.* with the earth, after removing it from the sphere *M.* it will be found charged with an excess of the electricity opposite to that of *M.*

"In all these experiments on induction, the charged sphere *M.* the inducing body, suffers no loss of electricity from having exercised its inductive action."

Lardner's Natural Philosophy, Chap. VIII.

(1769.) "*Electric forces investigated by Coulomb.*—It is not enough to ascertain the principles which govern the decomposition of the natural electricity of bodies, and"

"the reciprocal attraction and repulsion of the constituent fluids. It is also necessary to determine the actual amount of force exerted by each fluid in repelling fluid of the like, or attracting fluid of the opposite kind, and how the intensity of this attraction is varied by varying the distance between the bodies which are invested by the attracting or repelling fluids.

By a series of experimental researches, which rendered his name for ever memorable, Coulomb solved this difficult and delicate problem, measuring with admirable adroitness and precision these minute forces by means of his electroscope or balance of torsion already described (1756*)."

Fg.504.

(1770.) "*Proof-plane.*—The electricity of which the force was to be estimated, was taken up from the surface of the electrified body upon a small circular disc *C.*, Fig. 504, coated with metallic foil, and attached to the extremity of a delicate rod or handle *A. B.* of gum-lac. This disc, called a *Proof-plane*, was presented to the ball suspended in the electrometer of torsion (1756*), and the intensity

*(1756) "*Coulomb's Electroscope.*—The electroscope of Coulomb, better known as the balance of torsion, is an apparatus still more sensitive and delicate for indicating the existence and intensity of electrical force. A needle *g. g.* (Fig. 495), formed of gum-lac, is suspended by a fibre of raw silk *f.* At one extremity it carries a small disk *e*, coated with metallic foil, and is so balanced at the point of suspension, that the needle resting horizontally is free to turn in either direction round the point of suspension. When it turns, it produces a degree of torsion or twist of the fibre which suspends it, the reaction of which measures the force which turns the needle. The thread is fixed at the top to a small windlass *t*, by which the needle can be raised or lowered, and the whole is included in a glass cage, to preserve the apparatus from the disturbance of the air. Upon this glass cage, which is cylindrical, is a graduated circle *d. d.* which measures the

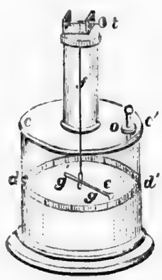

Fig. 495.

"of its attraction or repulsion was measured by the number of degrees through which the suspending fibre or wire was twisted by it.

The extreme degree of sensibility of this apparatus may be conceived, when it is stated that a force equal to the 304th part of a grain was sufficient to turn it through 360 degrees; and since the reaction of torsion is equal to the angle of torsion, the force necessary to make the needle move through one degree would be only the 122,400 part of a grain. Thus this balance was capable of dividing a force equal to a single grain weight into 122,400 parts, and rendering the effect of each part distinctly observable and measurable."

(1771.) "*Law of electrical force similar to that of gravitation.*—By these researches it was established, that the attraction and repulsion of the electric fluids, like the force of gravitation, and other physical influences which radiate from a centre, vary according to the common law of the *inverse square of the distance;* that is to say, the attraction or repulsion exerted by a body charged with electricity, or, to speak more correctly, by the electricity with which such a body is charged, increases in the same proportion as the square of the distance from the body on which it acts is diminished, and diminishes as the square of that distance is increased.

In general, if f. express the force exerted by any quantity of electric fluid, positive or negative, at the unit of distance, $\frac{f}{D^2}$ will express the force which the same quantity of the same fluid will exert at the distance D.

In like manner, if the quantity of fluid taken as the unit exercise at the distance D. the force expressed by $\frac{f}{D^2}$,"

angle through which the needle is deflected. In the cover of the cage an aperture *o*. is made, through which may be introduced the electrified body whose force it is desired to indicate and measure by the apparatus.

"the quantity expressed by $E.$ will exert at the same distance $D.$ the force $F.$ expressed by

$$F = \frac{f \times E}{D^2}$$

These formulæ have been tested by numerous experiments made under every possible set of conditions, and have been found to represent the phenomena with the greatest precision." *

1772. "*Distribution of the electric fluid on conductors.*—The distribution of electricity upon conductors can be deduced as a mathematical consequence of the laws of attraction and repulsion which have been explained above, combined with the property in virtue of which conductors give free play to these forces. The conclusions thus deduced may further be verified by the *Proof-plane* and electrometer of torsion, by means of which the fluid diffused upon a conductor may be *gauged*, so that its depth or intensity at every point may be exactly ascertained; and such depths and intensities have accordingly been found to accord perfectly with the results of theory."

1773. It is confined to their surfaces.—"Numerous facts suggest the conclusion that the electricity with which a conductor is charged is either superficial, or very nearly so.

If an electrified conductor be pierced with holes a little greater than the Proof-plane (Fig. 504) to different depths, that plane, inserted so as to touch the bottom of these holes, will take up no electricity.

If a spheroidal metallic body $A.$ (Fig. 505) suspended by a silken thread, be electrified, and two thin hollow "

* We opine that this statement is not warranted by the circumstances. To prevent complicating the case, we will not now examine the experiments alluded to. (N.B.—The value of the formulæ is entirely dependent on the results of the experiments which they purport to represent.)

" to fit, it coated on their inside caps *B. B.* and *B.′ C.′* made with metallic foil, and having insulating handles, *C. C.′* of gum-lac, be applied to it, on withdrawing them the spheroid will be deprived of its electrictiy, the fluid being taken off by the caps.

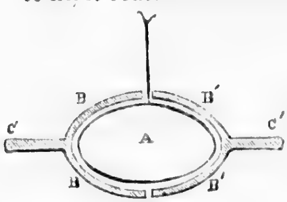

Fig. 505

Although it follows, from these and other experimental tests, as well as fromtheory, that the diffusion of electricity on conductors is nearly superficial, it is not absolutely so. If one end of a metallic rod coated with sealing-wax, be presented to any source of electricity, the fluid will be received as freely from the other end as if its surface were not coated with a non-conductor. It follows from this that the electricity must pass along the rod sufficiently within the surface of the metal, which is in contact with the wax, to be out of contact with the wax, which, by its insulating virtue, would arrest the progress of the fluid.

1774. *How the distribution varies.*—It remains, however, to ascertain how the intensity of the fluid, or its depth, on different parts of a conductor, varies.

There are some bodies whose form so strongly suggests the inevitable uniformity of distribution. If, then, the fluid be regarded as having an uniform depth on every part of a conducting sphere, exactly as a liquid might be uniformly diffused over the surface of the globe, the total quantity of fluid will be expressed by multiplying its depth by the superficial area of the globe.

1775. *Distribution on an ellipsoid.*—If the electrified conductor be not a globe, but an elliptical spheroid, such as *A. A.′* (Fig. 506), the fluid will be found to be accumulated in greater quantity at the ends *A.* and *A.* than at the sides *B. B.′* where there is less curvature. This unequal distribution of the fluid is represented by the dotted line in the figure."

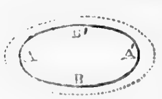

Fig. 506.

"It follows from theory, and it is confirmed by observation, that the depth of the fluid at *A.* and *A′.* is greater than at *B. B′.* in the ratio of the longer axis *A. A′.* of the eclipse to the shorter axis *B. B′.* If, therefore, the ellipsoid be very elongated, as in Fig. 506, the depth of the fluid at the ends *A.* and *A′.* will be proportionally greater.

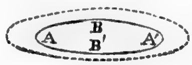

Fig. 507.

(1776.) "*Effects of edges and points.*—If the conductor be a flat disc, the depth of the fluid will increase from its centre towards its edges. The depth will, however, not vary sensibly near the centre, but will augment rapidly in approaching the edge, as represented in Fig. 508, where *A.* and *B.* are the edges and *C.* the centre of the disc, the depth of the fluid being indicated by the dotted line.

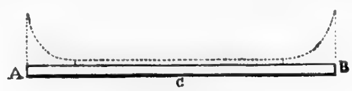

Fig. 508.

It is found in general that the depth of the fluid increases in a rapid proportion in approaching the edges, corners, and extremities, whatever be the shape of the conductor. Thus, when a circular disc or rectangular plate has any considerable magnitude, the depth of the electricity is sensibly uniform at all parts not contiguous to the borders; and whatever be the form, whether round or square, if only it be terminated by sharp, angular edges, the depth will increase rapidly in approaching them.

If a conductor be terminated, not by sharp, angular edges, but by rounded sides or ends, then the distribution will become more uniform. Thus, if a cylindrical conductor of considerable diameter have hemispherical ends, the distribution of the electricity upon it will be nearly uniform; but if its ends be flat, with sharp, angular edges, then an accumulation of the fluid will be produced"

"contiguous to them. If the sides of a flat plate of sufficient thickness be rounded, the accumulation of fluid at the edges will be diminished.

The depth of the fluid is still more augmented at corners where the increase of depth due to two or more edges meet and are combined; and this effect is pushed to its extreme limit if any part of a conductor have the form of a *point.*

The pressure of the surrounding air being the chief, if not the only force, which retains the electric fluid on a conductor, it is evident that if at the edges, corners, or angular points, the depth be so much increased that the elasticity of the fluid exceeds the restraining pressure of the atmosphere, the electricity must escape, and in that case will issue from the edge, corner, or point exactly as a liquid under strong pressure would issue from a *jet d'eau.*"

(1777.) "*Experimental illustration of the effect of a point.*—Let *P.* (Fig. 509) be a metallic point attached to a conductor *C.*, and let the perpendicular *n.* express the thickness or density of the electric fluid at that place; this thickness will increase in approaching the point *P.* so as to be represented by perpendiculars drawn from the respective points of the course *n.n'.n''.* to *A. P.* so that its density at *P.* will be expressed at the perpendicular *n''. P.* Experience shows that in ordinary states of the atmosphere a very moderate charge of electricity given to the conductor *C.* will produce such a density of the electric fluid at the point *P.* as to overcome the pressure of the atmosphere, and to cause the spontaneous discharge of the electricity.

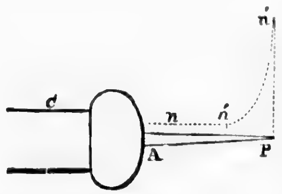

Fig. 509.

The following experiments will serve to illustrate the escape of electricity from points:"

Let a metallic point, such as *A. P.*, (Fig. 509), be attached to a conductor, and let a metallic ball of two or three inches in diameter, having a hole in it corresponding to the point *P.*, be stuck upon the point. If the conductor be now electrified, the electricity will be diffused over it, and over the ball which has been stuck upon the point *P.* The electric state of the conductor may be shown by a quadrant electrometer being attached to it. Let the ball now be drawn off the point *P.* by a silk thread attached to it for the purpose, and let it be held suspended by that thread. The electricity of the conductor *C.* will now escape by the point *P.*, as will be indicated by the electrometer, but the ball suspended by the silk thread will be electrified as before."

(1778.) "*Rotation produced by the reaction of points.*— Let two wires *A. B.* and *C. D.*, (Fig. 510) placed at right angles, be supported by a cap *E.* upon a fine point at the top of an insulating stand, and let them communicate by a chain *F.* with a conductor kept constantly electrified by a machine. Let each of the four arms of the wires be terminated by a point in a horizontal direction at right angles to the wire, each point being turned in the same direction, as represented in the figure.

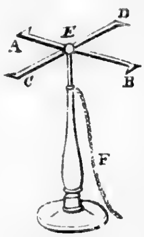

Fig. 510.

When the electricity comes from the conductor to the wires it will escape from the wires at these four points respectively; and the force with which it leaves them will be attended with a proportionate recoil,* which will cause the wire to spin rapidly on the centre *E.*

* It may be well again to remind the reader of the hypothesis of an imponderable but material fluid . . . a hypothesis scientifically inadmissible, but which Dr. Lardner appears to have practically accepted. Disallowing that hypothesis, it does not quite follow that the electric force, being spiritual, may not or might not have an action on the particles of air such as seems to be here indirectly attributed to it ; we opine, how-

(1779.) "*Another experimental illustration* of this principle.—An apparatus supplying another illustration of this principle is represented in Fig. 511; a square wooden stand *T.* has four rods of glass inserted in its corners, the rods at one end being less in height than those at the other. The tops of these rods having metal wires *A. B.* and *C. D.* stretched between them, across these wires another wire *E. F.* is placed, having attached to it at right angles another *G. H.* having two points turned in opposite directions at its extremities, so that when *G. H.* is horizontal these two points shall be vertical, one being presented upwards and the other downwards. A chain from *B.* communicates with a conductor kept constantly electrified by a machine. The electricity coming from the conductor by the chain, passes along the system of wires and escapes at the points *G.* and *H.* The consequent recoil causes the wire *G. H.* to revolve round *E. F.* as an axis, and thereby causes *E. F.* to roll up the inclined plane."

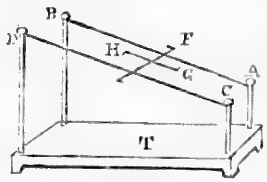

Fig. 511.

(1794.) "*Curious effect of repulsion of pith ball.*—Let a metallic point be inserted into one of the holes of the prime conductor, so that, in accordance with what has been explained, a jet of electricity may escape from it when the conductor is electrified. Let this jet, while the machine is worked, be received on the interior of a glass tumbler, by which the surface of the glass will become charged with electricity.

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ever, that the evidence is quite insufficient to substantiate such conclusion. If the effect is *recoil* in the material and usual sense, the case is one of action and reaction. Evidently the air should have motion imparted to it. Is there any evidence of such effect? Let the apparatus with its four arms (Fig. 510) be prevented from rotating, and let it be shown that the escape or discharge of electricity causes motion in the air in the opposite direction, *i.e.*, moves away the air from each of the points, tangentially to the circle.

If a number of pith balls be laid upon a metallic plate communicating with the ground, and the tumbler be placed with its mouth upon the plate, including the balls within it, the balls will begin immediately leaping violently from the metal and striking the glass, and this action will continue till all the electricity with which the glass was charged has been carried away.

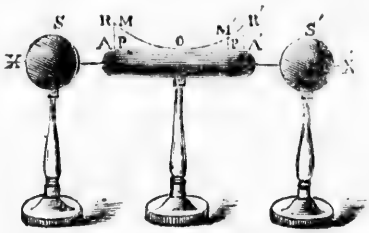
This is explained on the same principle as the former experiments. The balls are attracted by the electricity of the glass, and when electrified by contact, are repelled. They give up their electricity to the metallic plate from which it passes to the ground; and this process continues until no electricity remains on the glass of sufficient strength to attract the balls."

(1728.) "INDUCTION—*Action of Electricity at a distance.* —If a body *A.* charged with electricity of either kind be brought into proximity with another body *B.* in its natural state, the fluid with which *A.* is surcharged will act by attraction and repulsion on the two constituents of the natural electricity of *B.* attracting that of the contrary, and repelling that of the same kind. This effect is precisely similar to that produced on the natural magnetic fluid in a piece of iron when the pole of a magnet is presented to it.

If the body *B.* in this case be a non-conductor, the electric fluid having no free mobility on its surface, its decomposition will be resisted, and the body *B.* will continue in its natural state, notwithstanding the attraction and repulsion exercised by *A.* on the constituents of its natural electricity. But if *B.*, be a conductor, the fluids having freedom of motion on its surface, the fluid similar to that with which *B.* is charged will be repelled to the side most distant from *B.* and the contrary fluid will be attracted to the side next to *B.* Between these regions a neutral line will separate those parts of the body *B.* over which the two opposite fluids are respectively diffused."

(1729.) "*Induction Defined.*—This action of an electrified body exerted at a distance upon the electricity of another body is called *Induction*, and is evidently analogous to that which produces similar phenomena in the magnetic bodies (1630.)"

(1730.) "*Experimental Exhibition of its Effects.*—To render it experimentally manifest, let *S.* and *S'.*, Fig. 476, be two metallic balls, supported on glass pillars:



and let *A. A'.* be a metallic cylinder similarly mounted, whose length is ten or twelve times its diameter, and whose ends are rounded into hemispheres. Let *S.* be strongly charged with positive, and *S'.* with negative electricity, the cylinder *A. A'.* being in its natural state. Let the balls *S.* and *S'.* be placed near the ends of the cylinder *A. A'.* their centres being in a line with its axis, as represented in the figure.

The positive electricity of *S.* will now attract the negative, and repel the positive constituent of the natural electricity of *A. A'.*, so as to separate them, drawing the negative fluid towards the end *A.* and repelling the positive fluid towards the end *A'.*

Since the cylinder *A. A'.* is a conductor, and therefore the fluids have freedom of motion on its surface, this decomposition will take effect, and the half *O. A.* of the cylinder next to *S.* will be charged with negative, and the half *O. A'.* next to *S'.* with positive electricity.

That such is in fact the condition of *A. A'.* may be proved by presenting a pith ball pendulum charged with positive electricity to either half of the cylinder. When"

"presented to $O. A'$. it will be repelled, and when presented to $O. A$. it will be attracted.

If the two balls $S. S'$. be gradually removed to increased but equal distances from the ends A. and A'., the composition of the fluids will gradually take place; and when the balls are altogether removed the cylinder $A. A'$. will recover its natural state, the fluids which had been separated by the action of the balls being completely recombined by their mutual attraction.

Let a metallic ring n'. be supported on a rod or hook of glass n., and let two pith balls b. b'. be suspended from it by fine wires, so that when hanging vertically they shall be in contact. Let a ball of metal r., strongly charged with positive electricity, be placed over the ring n'. at a distance of eight or ten inches above it. The presence of this ball will immediately cause the pith balls to repel each other, and they will diverge to increased distances the nearer the ball r. is brought to the ring n'.

Fig. 477.

If the ball r. be gradually raised to greater distances from the ring, the balls b. b'. will gradually approach each other, and will fall to their position of rest vertically under the ring when the ball r. is altogether removed. If the charge of electricity of the balls S. and S'., Fig. 476, or of the ball r., Fig. 477, be gradually diminished, the same effect will be produced as when the distance is gradually increased; and, in like manner, the gradual increase of the charge of electricity will have the same effect as the gradual diminution of the distance from the conductor on which the action takes place.

If the ring n'., the balls b. b'., and the connecting wire be first feebly charged with negative electricity, and then submitted to the inductive action of the ball r. charged with positive electricity, placed as before above the ring, the following effects will ensue. When the ball r."

"approaches the ring, the balls *b. b'.* which previously diverged, will gradually collapse until they come into contact. As the ball *r.* is brought still nearer to *n'.* they will again diverge, and will diverge more and more, the nearer the ball *r.* is brought to the ring.

These various effects are easily and simply explicable by the action of the electricity of the ball *r.* on that of the ring. When it approaches the ring, the positive electricity with which it is charged decomposes the natural electricities of the ring, repelling the positive fluid towards the balls. This fluid combining with the negative fluid* with which the balls are charged, neutralises it, and reduces them to their natural state: while this effect is gradually produced, the balls *b. b'.* lose their divergence and collapse. But when the ball *r.* is brought still nearer to the ring, as more abundant decomposition of the natural fluid is produced, and the positive fluid repelled towards the balls is more than enough to neutralise the negative fluid with which they are charged; and the positive fluid prevailing, the balls again diverge with positive electricity.

These effects are aided by the attraction exerted by the positive electricity of the ball *r.* on the negative fluid with which the balls *b. b'.* are previously charged.

If the electrified ball, instead of being placed above the ring, be placed at an equal distance below the balls *b. b'.*, a series of effects will be produced in the contrary order, which the student will find no difficulty in analyzing and explaining. If the ball *r.* be charged with negative, it will produce the same effects when presented"

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* If we reject the dual-fluid hypothesis, the explanation will differ from the above, inasmuch as there will then be no negative fluid to neutralise. The balls have been, in the first place, deprived of their electricity; but the approach of the ball *r.* charged with positive electricity, repels the electricity from the ring to the balls which thus acquiring their natural (normal) amount of electricity no longer repel each other and fall together.

"above the ring, as when, being charged with positive electricity, it is presented below it.

In all cases whatever, the conductor whose electrical state has been changed by the proximity of an electrified body returns to its primitive electrical condition when the disturbing action of such body is removed*; and this return is either instantaneous or gradual."

(1731). "*Effects of Sudden Inductive Action.*—"It appears, therefore, that sudden and violent changes in the electrical condition of a conducting body may take place, without either imparting to or abstracting from such body any portion of electricity. The electricity with which it is invested before the inductive action commences, and after such action ceases, is exactly the same; nevertheless, the decomposition and recomposition of the constituent fluids, and their motion more or less sudden over it, and through its dimensions are productive often of mechanical effects of a very remarkable kind. This is especially the case with imperfect conductors, which offer more or less resistance to the reunion of the fluids."

(1732.) "*Example in the case of a frog.*—Let a frog be suspended by a metallic wire which is connected with an insulated conductor, and let a metallic ball, strongly charged with positive electricity, be brought under, without, however, touching it. The effects of induction already described will ensue. The positive fluid will be repelled from the frog towards the insulated conductor, and the negative fluid will be attracted towards it, so that the body of the frog will be negatively electrified; but this taking place gradually as the electrified ball approaches, is attended with no sensible effect. If the electrified ball, however, be suddenly discharged, by connecting it with the ground by a conductor, an instan-"

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* This statement as it stands is directly contradicted by what follows, Art. 1731. By the word conductor here it must be understood that *insulated* conductor is intended.

"taneous revulsion of the electric fluids will take place between the body of the frog and the insulated conductor, with which it is connected; the positive fluid rushing from the conductor, and the negative fluid from the frog. to recombine in virtue of their mutual attraction. This sudden movement of the fluids will be attended by a convulsive motion of the limbs of the frog."

(1733.) "*Inductive shock of the human body.*—If a person stand close to a large conductor strongly charged with electricity, he will be sensible of a shock when this conductor is suddenly discharged. This shock is in like manner produced by the sudden recomposition of the fluids in the body of the patient, by the previous inductive action of the conductor."

(1734.) "*Development of Electricity by Induction.*—A conductor may be charged with electricity by an electrified body, though the latter shall not lose any of its own electricity or impart any to the conductor so electrified. For this purpose, let the conductor to be electrified be supported on a glass pillow so as to insulate it, and let it then be connected with the ground by a metallic chain or wire. If it be desired to charge it with positive electricity, let a body strongly charged with negative electricity be brought close to it without touching it. On the principle already explained, the negative electricity of the conductor will be repelled to the ground through the chain or wire; and the positive electricity will, on the other hand, be attracted from the ground to the conductor. Let the chain or wire be then removed, and, afterwards, let the electrified body, by whose inductive action the effect is produced, be removed. The conductor will remain charged with positive electricity. It may in like manner be charged with negative electricity, by the inductive action of a body charged with positive electricity.*"

For some further particulars of "Inductive Action," see Appendix.

* In this case the conductor connected with the ground and the

To apply these examples to the case of the comet. If we consider the sun as the body charged with electricity and the comet as the insulated conductor, it becomes readily understood that the inductive power of the sun will cause the electricity of the comet to accumulate on the side opposite to itself. We have already called attention to the fact that the action of heat on material bodies causes an elimination of electricity, or, in other words, that caloric force (heat) is convertible into free volumetric electricity. The sun's action on the comet, (causing an increased development of free electricity on the surface of the latter,) will consequently result in an accumulation of electricity at the side of the comet most remote from the sun, and which, being luminous, will account for the observed phenomenon known as the luminous train. It may be remarked that when the distance from the sun again becomes greater, a part of the free electricity may be reconverted into caloric force (heat,) and the quantity undergo decrease by its communication as radiant heat to other aggregated masses of matter.

The following is a distinct example of the luminiferous character of electricity; that is, of the close connection between Volumetric Electricity and Luminiferous Force (and also Mechanical Effect.)

Lardner's Natural Philosophy. (1796.) *Curious exper-*

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ground itself should be looked upon as one conductor, so long as they are connected. Therefore, removing the chain or wire cuts off the communication between the one part of the conductor and the other. Rejecting the dual-hypothesis, the explanation will be that the body charged with negative electricity) which has been deprived or denuded of its electricity, attracts or induces a quantity of electricity to that part of the conductor nearest to it. The chain being removed and the inducing body being afterwards also removed, the electricity accumulated in that part of the conductor (now insulated) is unable to return, and consequently remains in excess of the quantity which naturally or normally (so to speak) belongs to that part of the conductor.

iments on electrified water.—"Let a small metallic bucket *B.*, Fig. 519, be suspended from the prime conductor of a machine, and let it have a capillary tube *C. D.*, of the siphon form, immersed in it; or let it have a capillary tube inserted in the bottom; the bore of the tube being so small that water cannot escape from it by its own pressure. When the machine is put in operation, the particles of water, becoming electrified, will repel each other, and immediately an abundant stream will issue from the tube; and as the particles of water after leaving the tube still exercise a reciprocal repulsion, the stream will diverge in the form of a brush.

If a sponge, saturated with water, be suspended from the prime conductor of the machine, the water, when the machine is first worked, will drop slowly from it; but when the conductor becomes strongly electrified, it will descend abundantly, and in the dark will exhibit the appearance of a shower of luminous rain."

(Note. In connection with this the reader may be reminded of the occasionally luminous appearance of (sea-water) the surface of the ocean in the very beautiful phenomenon known as the phosphorescence of the sea.*)

We will now give some examples from the general record of facts for the purpose of briefly illustrating the close relationship or correlation of the several forms of force—*i.e.*, the several physical forces.

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* This phenomenon is usually attributed, incorrectly, we opine, to the presence of some form of animal or vegetable life, which is supposed to be distributed on the surface in vast numbers of minute individuals.

ELECTRICITY AND MECHANICAL EFFECT.

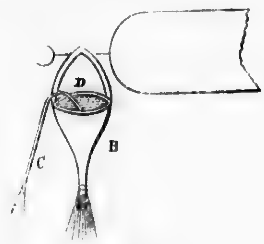

Fig. 519.

ELECTRIC TY AND MAGNETISM.

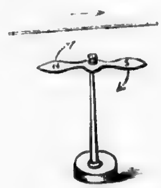

Fig. 52.

HEAT AND ELECTRICITY.

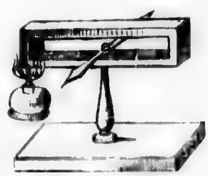

Fig. 54 (a).

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Fowne's Manual of Chemistry. Part I. Physics, page 72.—"Not long before two very remarkable facts had been discovered. Oersted, in Copenhagen, showed that a current of electricity, however produced, exercises a singular and perfectly definite action on a magnetic needle; and Seebeck, in Berlin, found that an electric current may be generated by the unequal effects of heat on different metals in contact. If a wire conveying an electrical current be brought near a magnetic needle, the latter will immediately alter its position and assume a new one, as nearly perpendicular to the wire as the mode of suspension and the magnetism of the earth will permit. When the wire, for example, is placed directly over the needle, while the current it carries travels from north to south, the needle is deflected from its ordinary direction and the north pole driven to the eastward. When the current is reversed, the same pole deviates to an equal amount towards the west. Placing the wire below the needle instead of above produces the same effect as reversing the current.

Fig. 53.

When the needle is subjected to the action of two currents in opposite directions, the one above and the other below, they will obviously concur in their effects. The same thing happens when the wire carrying the current is bent upon itself, and the needle placed between the two portions; and since every time the bending is repeated a fresh portion of the current is made to act in the same manner upon the needle, it is easy to see how a current, too feeble to produce any effect when a single straight wire is employed, may be made by this contrivance to exhibit a power-"

"ful action on the magnet. It is on this principle that instruments called *galvanometers*, *galvanoscopes*, or *multipliers* are constructed; they serve, not only to indicate the existence of electrical currents, but to show by the effect upon the needle the direction in which they are moving. By using a very long coil of wire, and two needles, immovably connected, and hung by a fine filament of silk, almost any degree of sensibility may be communicated to the apparatus.*

When two pieces of different metals connected together at each end, have one of their points more heated than"

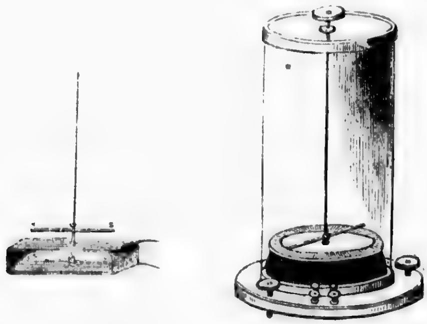


Fig. 69.

* The common galvanoscope, consisting of a coil of wire having a compass-needle suspended on a point within it, is greatly improved by the addition of a second needle, as already in part described, and by a better mode of suspension, a long fibre of silk being used for the purpose. The two needles are of equal size, and magnetized as nearly as possible to the same extent; they are then immovably fixed together, parallel, and with their poles opposed, and hung with the lower needle in the coil and the upper one above it. The advantage gained is two-fold: the system is *astatic*, unaffected, or nearly so, by the magnetism of the earth; and the needles being both acted upon in the same manner by the current, are urged with much greater force than one alone would be, all the actions of every part of the coil being strictly concurrent. A divided circle is placed below the upper needle, by which the regular motion can be measured; and the whole is enclosed in glass, to shield the needles from the agitation of the air. The whole is shown in Fig. 69.

"the other, an electric current is immediately set up. Of all the metals tried, bismuth and antimony form the most powerful combination. A single pair of bars, having one of their junctions heated in the manner shown, can develope a current strong enough to deflect a compass-needle placed within, and, by arranging a number in a series and heating their alternate ends, the intensity of the current may be very much increased. Such an arrange-

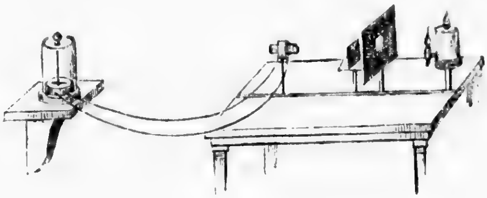


Fig. 54.

ment is called a thermo-electric pile. M. Melloni constructed a very small thermo-electric pile of this kind, containing fifty-five slender bars of bismuth and antimony, laid side by side and soldered together at their alternate ends. He connected this pile with an exceedingly delicate multiplier, and found himself in the possession of an instrument for measuring small variations of temperature far surpassing in delicacy the air-thermometer in its most sensitive form, and having great advantages in other respects over that instrument when employed for the purposes to which he devoted it." (See Fig. 54).

By means of this apparatus, the close analogy between radiant heat and light was made apparent. The example here given illustrates the conversion of heat (caloric force) into molecular-electricity (voltaic electric-force).

Examples of the connection between Volumetric (frictional), and Molecular (voltaic) Electricity are . . . The production of Magnetism . . . Chemical decomposition . . . The production of (conversion into) Heat. (*e.g.*, in the heat-

ing and fusion of a conducting wire) ... effects, which may result from the action of either one of those forces or forms of force on compound matter. And the relation of 'motion' and 'mechanical-effect' to each of those forces is shown in the production of volumetric electricity by friction in the plate or cylinder electrical machine; and in the production of molecular electricity by the rotation of an armature (a piece of iron) in front of the poles of a magnet. The production of volumetric electricity by a jet of steam also shows the connection of that force with mechanical-effect, and also with heat (because the mechanical effect of the steam results from the addition of caloric force to the water.) And in, again, the development of the same kind of electricity (volumetric) by or in certain animals (fishes)—*e. g.*, the Gymnotus, electricity is seen to be closely connected with nervous power, (*i. e.*, with mechanical-effect)... the electrical shock is given at the will of the animal, and great exhaustion follows the repeated exertion of the power.

The proposition that compound matter is compounded of force together with matter, and that the distinctive characteristics of the compound substance are dependent upon the definite proportional quantity of force which enters into its composition and constitutes a part of it, may be demonstrated by the facts belonging to chemical and physical science. The following will here suffice to indicate and illustrate the connection.

Lardner's Natural Philosophy.

(1799.) "*A Current of Electricity passing over a Conductor raises its Temperature.*—If a current of electricity pass over a conductor, as would happen when the conductor of an electrical machine is connected by a metallic rod with the earth, no change in the thermal condition of the conductor will be observed so long as its transverse section is so considerable as to leave sufficient space for the free passage of the fluid. But if its thickness be diminished, or the quantity of fluid passing over it be

augmented, or, in general, if the ratio of the fluid to the magnitude of the space afforded to it be increased, the conductor will be found to undergo an elevation of temperature, which will be greater the greater the quantity of the electricity and the less the space supplied for its passage."

(1800.) "*Experimental Verification,—Wire heated, fused, and burned*—If a piece of wire of several inches in length be placed upon the stage of the universal discharger, a feeble charge transmitted through it will sensibly raise its temperature. By increasing the strength of the charge, its temperature may be elevated to higher and higher points of the thermometric scale; it may be rendered incandescent, fused, vaporized, and, in fine, burned.

With the powerful machine of the Taylerian Museum at Haarlem, Van Marum fused pieces of wire above 70 feet in length.

Wire may be fused in water; but the length which can be melted in this way is always less than in air, because the liquid robs the metal of its heat more rapidly than air.

A narrow ribbon of tinfoil, from 4 to 6 inches in length, may be volatilized by the discharge of a common battery. The metallic vapor is, in this case, oxidized in the air, and its filaments float like those of a cobweb."

(1801.) "*Thermal Effects are greater as the Conducting Power is less.*—These thermal effects are manifested in different degrees in different metals, according to their varying powers. The worst conductors of electricity, such as platinum and iron, suffer much greater changes of temperature by the same charge than the best conductors, such as gold and copper. The charge of electricity, which only elevates the temperature of one conductor, will sometimes render another incandescent, and will volatilize a third."

(1802.) "*Ignition of Metals.*—If a fine silver wire be

extended between the rods of the universal discharger, a strong charge will make it burn with a greenish flame. It will pass off in a greyish smoke; other metals may be similarly ignited, each producing a flame of a peculiar color. If the experiments be made in a receiver, the products of the combustion being collected, will prove to be the metallic oxides.

If a gilt thread of silk be extended between the rods of the discharger, the electricity will volatilize or burn the gilding, without affecting the silk. The effect is too rapid to allow the time necessary for the heat to affect the silk.

A strip of gold or silver leaf placed between the leaves of paper, being extended between the rods of the discharger, will be burnt by a discharge from a jar having two square feet of coating. The metallic oxide will in this case appear on the paper as a patch of purple color in the case of gold, and of grey color in that of silver.

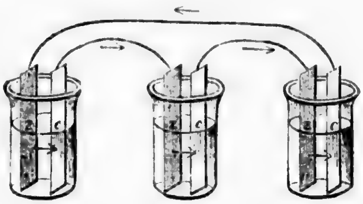
A spark from the prime conductor of the great Haarlem machine burnt a strip of gold leaf twenty inches long by an inch and a half broad."

(1806.) "*Resinous Powder Burned.*—The electric charge transmitted through fine resinous powder, such as that of Colophony, will ignite it. This experiment may be performed either by spreading the powder on the stage of the discharger, or by impregnating a hank of cotton with it; or, in a still more striking manner, by sprinkling it on the surface of water contained in an earthenware saucer."

MOLECULAR (VOLTAIC) ELECTRICITY AND MATTER.

Fowne's Chemistry, Page 92.—The second form of apparatus, or crown of cups, is precisely the same in principle, although different in appearance. A number of cups or glasses are arranged in a row or circle, each containing a piece of active and a piece of inactive metal

"and a portion of exciting liquid; zinc, copper, and dilute sulphuric acid, for example. The copper of the first cup is connected with the zinc of the second, the copper of the second with the zinc of the third, and so to the end of the series. On establishing a communication between the first and last plates by means of a wire, or otherwise, discharge takes place in the form of a bright enduring spark or stream of fire."



(Page 206). "When a voltaic current of considerable power is made to traverse various compound liquids, a separation of the elements of these liquids ensues; provided that the liquid be capable of conducting a current of a certain degree of energy, its decomposition almost directly follows.

The elements are disengaged solely at the limiting surface of the liquid; where, according to the common mode of speech, the current enters and leaves the latter, all the intermediate portions appearing perfectly quiescent. In addition, the elements are not separated indifferently and at random at these two surfaces, but, on the contrary, make their appearance with perfect uniformity and constancy at one or the other, according to their chemical character, namely—oxygen, chlorine, iodine, acids, etc., at the surface connected with the *copper* or *positive* end of the battery; hydrogen, the metals, etc., at the surface in connection with the *zinc* or *negative* extremity of the arrangement.

The terminations of the battery itself, usually, but by no means necessarily of metal, are designated poles or"

"*electrodes*, as by their intervention the liquid to be experimented on is made a part of the circuit. The proc ss of decomposition by the current is called *electrolysic*, and the liquids, which, when thus treated, yield up their elements, are denominated *electrolytes*.

When a pair of platinum plates are plunged into a glass of water to which a few drops of oil of vitriol have been added, and the plates connected by wires with the extremities of an active battery, oxygen is disengaged at the positive electrode, and hydrogen at the negative, in the proportion of one measure of the former to two of the latter nearly.

A solution of hydrochloric acid mixed with a little Saxon blue (indigo), and treated in the same manner, yields hydrogen on the negative side, and chlorine on the positive, the indigo there becoming bleached.

Iodide of potassium dissolved in water is decomposed in a similar manner, and with still gr ater ease; the free iodine at the positive side can be recognized by its brown colour, or by the addition of a little gelatinous starch.

Every liquid is not an electrolyte; many refuse to conduct, and no decomposition can then occur; alcohol, ether, numerous essential oils, and other products of organic chemistry, besides a few saline inorganic compounds act in this manner, and completely arrest the current of a very powerful battery. It is a very curious fact, and well deserves attention, that very nearly, if not all the substances acknowledged to be susceptible of electrolytic decomposition, belong to one class; they are all binary compounds, containing single equivalents of their components, the latter being strongly opposed to each other in their chemical relations, and held together by very powerful affinities."

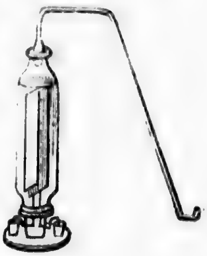
"The metallic terminations of the battery, the poles or electrodes, have, in themselves, nothing in the shape of attractive or repulsive power for the elements so often separated at their surfaces. Finely-divided metal sus- "

"pended in water, or chlorine held in solution in that liquid, shows not the least symptom of a tendency to accumulate around them; a single element is altogether unaffected, directly at least; severance from previous combination is required, in order that this appearance should be exhibited.

It is necessary to examine the processes of electrolysis a little more closely. When a portion of water, for example, is subjected to decomposition in a glass vessel with parallel sides, oxygen is disengaged at the positive electrode, and hydrogen at the negative; the gases are pure and unmixed. If, while the decomposition is proceeding, the intervening water be examined by a beam of light, or by other means, not the slightest disturbance or movement of any kind will be perceived, nothing like currents in the liquid or bodily transfer of gas from one part to another can be detected, and yet two portions of water, separated perhaps by an interval of four or five inches, may be respectively evolving pure oxygen and hydrogen."

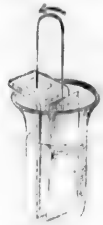
"If a number of different electrolytes, such as acidulated water, sulphate of copper, iodide of potassium, fused chloride of lead, &c., be arranged in a series, and the same current be made to traverse the whole, all will suffer decomposition at the same time, but by no means to the same amount. If arrangements be made by which the quantity of the eliminated elements can be accurately ascertained, it will be found, when the decomposition has proceeded to some extent, that these latter will have been disengaged exactly in the *ratio of the chemical equivalents.* The same current which decomposes 9 parts of water will separate into their elements 166 parts of iodide of potassium, 139·2 parts of chloride of lead, &c. Hence the very important conclusion: The action of the current is perfectly definite in its nature, producing a fixed and constant amount of decomposition, expressed in each electrolyte by the value of its chemical equivalent."

From a very extended series of experiments, based on this and other methods of research, Mr. Faraday was enabled to draw the general inference that effects of chemical decomposition were always proportionate to the quantity of circulating electricity, and might be taken as an accurate and trustworthy measure of the latter. Guided by this highly important principle he constructed his *voltameter*, an instrument which has rendered the greatest service to electrical science. This is merely an arrangement by which a little acidulated water is decomposed by the current, the gas evolved being collected and measured. By placing such an instrument in any part of the circuit, the quantity of electric force necessary to produce any given effect can be at once estimated; or, on the other hand, any required amount of the latter can be, as it were, measured out and adjusted to the object in view. The voltameter has received many different forms; one of the most extensively useful is that figured, in which the platinum plates are separated by a very small interval, and the gas is collected in a graduated jar standing on the shelf of the pneumetic trough, the tube of the instrument, which is filled to the neck with dilute sulphuric acid, being passed beneath the jar."



"The experiments of Mr. Faraday and Professor Daniell have given very great support to the chemical theory, by shewing that contact of dissimilar metals is not necessary in order to call into being powerful electrical currents, and that the development of electrical force is not only in some way connected with the chemical action of the liquid of the battery, but that it is always in direct proportion to the latter. One very beautiful experiment, in which the decomposition of iodide of potassium by real electrolysis is performed by a current generated

without any contact of dissimilar metals can be thus made: — A plate of zinc is bent at a right angle, and cleaned by rubbing with sand-paper. A platinum plate has a wire of the same metal attached to it by carefully rivetting, and the latter bent into an arch. A piece of folded filter-paper is wetted with solution of iodide of potassium, and placed upon the zinc; the platinum plate is arranged opposite to the latter, with the end of its wire resting upon the paper, and then the pair plunged into a glass of dilute sulphuric acid, mixed with a few drops of nitric. A brown spot of iodine becomes in a moment evident beneath the extremity of the platinum wire; that is, at the positive side of the arrangement.



A strong argument in favor of the chemical view is founded on the easily proved fact, that the direction of the current is determined by the kind of action upon the metals, the one least attacked being always positive. Let two polished plates, the one iron and the other copper, be connected by wires with a galvanometer, and then immersed in a solution of an alkaline sulphide. The needle in a moment indicates a powerful current, passing from the copper, through the liquid, to the iron, and back again through the wire. Let the plates be now removed, cleaned, and plunged into dilute acid; the needle is again driven round, but in the opposite direction, the current now passing from the iron, through the liquid, to the copper. In the first instance the copper is acted upon, and not the iron; in the second, these conditions are reversed, and with them the direction of the current."

"The principle of the compound battery is, perhaps, best seen in the crown of cups*; by each alternation of zinc, fluid, and copper, the current is urged forward with

* See Page 153.

increased energy, its intensity is augmented, but the actual amount of electrical force thrown into the current form* is not increased. The quantity estimated by its decomposing power is in fact determined by that of the smallest and least active pair of plates, the quantity of electricity in every part or section of the circuit being exactly equal. Hence large and small plates, batteries strongly and weakly charged, can never be connected without great loss of power."

"When a battery, either simple or compound, constructed with pure or amalgamated zinc, is charged with diluted sulphuric acid, a number of highly interesting phenomena may be observed. While the circuit remains broken the zinc is perfectly inactive, no water is decomposed, no hydrogen liberated; but the moment the connection is completed, torrents of hydrogen arise, not from the zinc, but from the copper or platinum surfaces alone, while the zinc undergoes tranquil and imperceptible oxidation and solution. Thus, exactly the same effects are seen to occur in every active cell of a closed circuit which are witnessed in a portion of water undergoing electrolysis; the oxygen appears at the positive side, with respect to the current, and the hydrogen at the negative; but with this difference, that the oxygen instead of being set free combines with the zinc.† It is, in fact, a real case of electrolysis, and electrolytes alone are available as exciting liquids."

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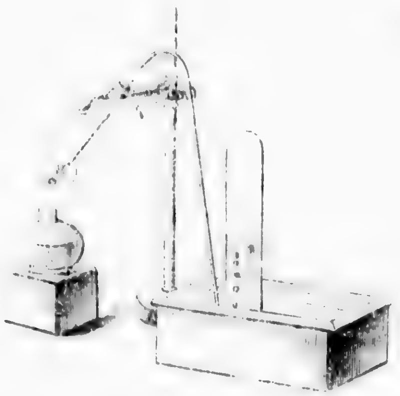
* i. e., The quantity of force rendered dynamic.

† *It may be therefore considered—a combustion of the zinc in which a definite quantity of molecular force is set free in the form of molecular (voltaic) electricity, instead of in the form of heat (caloric force) as in ordinary combustion—which last may be termed, for the sake of distinction, gaseous oxidation, the former being termed nascent or liquid oxidation.*

"From experiments very carefully made with a dissected battery of peculiar construction, in which local action was completely avoided, it has been distinctly proved that the quantity of electricity set in motion by the battery varies with the zinc dissolved. Coupling this fact with that of the definite action of the current, it will be seen that when a perfect battery of this kind is employed to decompose water, in order to evolve 1 grain of hydrogen from the latter, 33 grains of zinc must be oxidized and its equivalent quantity of hydrogen disengaged in each active cell of the battery. That is to say, that the electrical force generated by the oxidation of an equivalent of zinc in the battery, is capable of effecting the decomposition of an equivalent of water, or any other electrolyte out of it."

Fig. 73.



MOLECULAR FORCE AND THE MATERIAL ELEMENTS OF COMPOUND MATTER.

"The red oxide of mercury is placed in a short tube of hard glass, to which is fitted a perforated cork, furnished with a piece of narrow glass tube, bent as in the figure. The heat of a spirit lamp being applied to the substance, decomposition speedily commences, glo-"

"bules of metallic mercury collect in the cool part of the wide tube, which answers the purpose of a retort, while gas issues in considerable quantity from the apparatus. This gas is collected and examined by the aid of the pneumatic trough, which consists of a vessel of water provided with a shelf, upon which stand the jars or bottles destined to receive the gas, filled with water and inverted.

By keeping the level of the liquid above the mouth of the jar, the water is retained in the latter by the pressure of the atmosphere, and entrance of air is prevented. When brought over the extremity of the gas-delivery tube, the bubbles of gas rising through the water collect in the upper part of the jar and displace the liquid. As soon as one jar is filled, it may be removed, still keeping its mouth below the water level and another substituted. The whole arrangement is shown in Fig. 73.

The experiment described is more instructive as an excellent case of the resolution by simple means of a compound body into its constituents, than valuable as a source of oxygen gas. A better and more economical method is to expose to heat in a retort, or flask furnished with a bent tube, a portion of the salt called chlorate of potassa. A common Florence flask answers perfectly well, the heat of a spirit lamp being sufficient. The salt melts and decomposes with ebullition, yielding a very large quantity of oxygen gas, which may be collected in the way above described. The first portion of the gas often contains a little chlorine. The white saline residue in the flask is chloride of potassium."

These facts serve to show the intimate nature of the connection between chemical and electrical forces,—*i. e.*, between those forms of force.

We have adopted the term 'caloric-force' as including the two distinct forms or modes of heat known as *radiant* (or *free*) and *latent* (or *combined*) heat. Of these, *radiant* heat may be considered as nearly allied to volumetric electricity and to light; whilst *latent* heat appears to be more closely allied in its characteristics to molecular electricity, for it enters into and modifies or changes the internal physical condition of the compound matter.

The inter-relation of these two forms of force, namely, radiant and latent heat has to be now briefly considered. (*Note.*—It may be observed that the phenomena of latent heat (and of specific heat) together with those of isomorphism strongly support the proposition that compound matter consists of elementary matter compounded with force.

Fowne's Chemistry.—Heat . . . Change of State.

"If equal weights of water at 32°, and water at 174°, be mixed, the temperature of the mixture will be the mean of the two temperatures, or 103°. If the same experiment be repeated with snow, or finely powdered ice, at 32° and water at 174° the temperature of the whole will be still only 32°, *but the ice will have been melted.*

$$\left.\begin{array}{l}1 \text{ lb. of water at } 32^\circ.\\ 1 \text{ lb. of water at } 174^\circ.\end{array}\right\} = 2 \text{ lbs. water at } 103^\circ.$$

$$\left.\begin{array}{l}1 \text{ lb. of ice at } 32^\circ.\\ 1 \text{ lb. of water at } 174^\circ.\end{array}\right\} = 2 \text{ lbs. water at } 32^\circ.$$

In the last experiment, therefore, as much heat has been apparently lost as would have raised a quantity of"

"water equal to that of the ice through a range of 142
The heat, thus become insensible to the thermometer in effecting the liquefaction of the ice, is called latent heat, or better, heat of fluidity.

Again, let a perfectly uniform source of heat be imagined, of such intensity that a pound of water placed over it would have its temperature raised 10° per minute. Starting with water at 32° in rather more than 14 minutes, its temperature would have risen 142°; but the same quantity of ice at 32°, exposed for the same interval of time, would not have its temperature raised a single degree. But, then, it would have become water; the heat received would have been exclusively employed in effecting a change of state.

The heat is not lost, for when the water freezes it is again evolved. If a tall jar of water, covered to exclude dust, be placed in a situation where it shall be quite undisturbed, and at the same time exposed to great cold, the temperature of the water may be reduced 10° or more below its freezing-point without the formation of ice: but then if a little agitation be communicated to the jar, or a grain of sand dropped into the water, a portion instantly solidifies, and the temperature of the whole rises to 32°; the heat disengaged by the freezing of a small portion of the water will have been sufficient to raise the whole *contents* of the jar 10°." "The law thus illustrated in the case of water is perfectly general. Whenever a solid becomes a liquid, a certain fixed and definite amount of heat disappears or becomes latent, and conversely, whenever a liquid becomes a solid, heat to a corresponding extent is given out. The amount of latent heat varies much with different substances as will be seen by the table:—

Water..........	142°	Zinc..........	193°
Sulphur	145°	Tin	500°
Lead..........	162°	Bismuth.......	500°

"A law of exactly the same kind as that described affects universally the gaseous condition; change of state from solid or liquid to gas is accompanied by absorption of sensible heat, and the reverse by its disengagement. The latent heat of steam and other vapours may be ascertained by a similar mode of investigation to that employed in the case of water.

When water at 32° is mixed with an equal weight of water at 212° the whole is found to possess the mean of the two temperatures, or 122°; on the other hand, 1 part by weight of steam at 212° when condensed into cold water, is found to be capable of raising 5·6 parts of the latter from the freezing to theboiling point, or through a range of 180°. Now 180 + 5·6 = 1008; that is to say, steam at 212° in becoming water at 212°, parts with enough heat to raise a weight of water equal to its own (if it were possible) 1008° of the thermometer. When water passes into steam, the same quantity of sensible heat becomes latent." "It is a very remarkable fact, that the latent heat of steam diminishes as the temperature of steam rises, so that equal weights of steam thrown into cold water exhibit nearly the same heating power, although the actual temperature of the one portion may be 212° and that of the other 350°. This also appears true with temperatures below the boiling point; so that it seems, to evaporate a given quantity of water, the same absolute amount of heat is required, whether it be performed slowly at the temperature of the air, in a manner presently to be noticed, or whether it be boiled off under the pressure of twenty atmospheres."

Capacity for Heat; Specific Heat.

"Let the reader renew a supposition made when the doctrine of latent heat was under consideration: let him imagine the existence of an uniform source of heat, and"

"its intensity such as to raise a given weight of water 10° in 30 minutes. If, now, the experiment be repeated with equal weights of mercury and oil, it will be found, that instead of 30 minutes, 1 minute will suffice in the former case, and 15 minutes in the latter. This experiment serves to point out the very important fact, that different bodies have different *capacities for heat;* that equal weights of water, oil, and mercury, require, in order to rise through the same range of temperature,—quantities of heat in the proportion of the numbers 30, 15, and 1. This is often expressed by saying that the *specific heat* of water is 30 times as great as that of mercury, and the specific heat of oil 15 times as great."

"MM. Dulong and Petit observed in the course of their investigation a most remarkable circumstance. If the specific heats of bodies be computed upon equal weights, numbers are obtained, all different, and exhibiting no simple relations among themselves; but if, instead of equal weights, quantities be taken in the proportion of the chemical equivalents, an almost perfect coincidence in the numbers will be observed, shewing that some exceedingly intimate connection must exist between the relations of bodies to heat and their chemical nature."

CALORIC FORCE AND MECHANICAL EFFECT.

The following, taken also from *Fownes' Manual of Chemistry*, are instances of the correlation (inter-relation) of caloric-force and mechanical effect.

"An experiment of Count Rumford is on record, in which the heat developed by the boring of a brass cannon was sufficient to bring to the boiling point two and a half gallons of water, while the dust or shavings of metal, cut by the borer, weighed a few ounces only."

"Sir H. Davy melted two pieces of ice by rubbing them together in vacuo at 32°; and uncivilized men, in various parts of the world, have long been known to obtain fire by rubbing together two pieces of dry wood."

"A soft iron nail may be made red hot by a few dexterous blows on an anvil; but the experiment cannot be repeated until the metal has been *annealed*, and in that manner restored to its original physical state."

To these examples may be added, that of the heat given out by air and other gas when subjected to mechanical pressure,* and, that of the steam-engine in which a portion of the heat imparted to the water may be considered to be converted into mechanical effect.†

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* The 'caloric-engine' (of Ericson) in which the expansion of air by heat, furnishes the motive power, may be mentioned as another illustration.

† A little consideration will make apparent that a distinction should be made between the case of a high-pressure, and of a condensing engine; in the former the sensible (radiant) heat, which is contained in the steam above the temperature of 212° and occasions the pressure in excess of atmospheric pressure, may be considered as directly converted into mechanical effect; in the latter (the condensing engine) the latent heat contained in the steam through condensation of the steam and production of the vacuum, is, so to speak, indirectly converted into and utilized as mechanical effect.

Magnetism.—The phenomena belonging to what is termed magnetism are to be considered as included under the more general title molecular electricity. They are, however, advantageously studied as a separate class or subdivision.

For the purpose of distinguishing this division of the one form of force into two kinds of manifestation, the term 'magnetism' might be amplified into magnetic electricity, and molecular electricity be considered to comprise { Voltaic or Chemical electricity, Magnetic electricity.

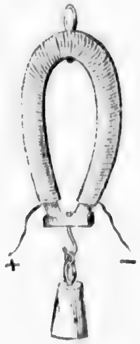
"The one class of phenomena belongs to the investigation of the influence of molecular electricity upon the elementary constituents of which compound matter is compounded, and the circumstances under which that influence causes those elements to combine or to separate. The other class—that of magnetic electricity—belongs to the investigation of the influence of molecular electricity on the various descriptions of compound matter. That magnetism is a manifestation of molecular (voltaic) electricity, is shown by the following:—

Fownes' Manual of Chemistry.

Page 96. "A little consideration will show that, from the peculiar nature of the electro-dynamic force, a wire carrying a current, bent into a spiral or helix, must possess the properties of an ordinary magnetized bar, its extremities being attracted and repelled by the poles of a magnet. Such is really found to be the case, as may be proved by a variety of arrangements, among which it will be sufficient to cite the beautiful little apparatus of Professor De la Rive: A short wide glass tube is fixed into a cork ring of considerable size; a little voltaic battery, consisting of a single pair of copper and zinc"

"plates, is fitted to the tube, and to these the ends of the spiral are soldered. On filling the tube with dilute acid and floating the whole in a large basin of water, the helix will be observed to arrange itself in the magnetic meridian, and on trial it will be found to obey a magnet held near it in the most perfect manner as long as the current circulates."

"When an electric current is passed at right angles to a piece of iron or steel, the latter acquires magnetic polarity; either temporay or permanent, as the case may be, the direction of the current determining the position of the poles. This effect is prodigiously increased by causing the current to circulate a number of times round the bar, which then acquires extraordinary magnetic power. A piece of soft iron, worked into the form of a horse-shoe, and surrounded by a coil of copper wire covered with silk or cotton for the purpose of insulation, furnishes an excellent illustration of the inductive energy in this respect; when the ends of the wire are put into communication with a small voltaic battery of a single pair of plates, the iron instantly becomes so highly magnetic as to be capable of sustaining a very heavy weight.



A current of electricity can thus develop magnetism in a transverse direction to its own; in the same manner magnetism can call into activity electric currents. If the two extremities of the coil of the electro-magnet above described be connected with a galvanoscope, and the iron magnetized by the application of a permanent steel horse-shoe magnet to the ends of the bar, a momentary current will be developed in the wire, and pointed out by the movement of the needle. It lasts but a single instant,"

"the needle returning after a few oscillations to a state of rest. On removing the magnet, whereby the polarity of the iron is at once destroyed, a second current or wave will become apparent, but in the opposite direction to that of the first.

By employing a very powerful steel magnet, surrounding its iron keeper or armature with a very long coil of wire, and then making the armature itself rotate in front of the faces of the magnet, so that its polarity shall be rapidly reversed, magneto-electric currents may be produced, of such intensity as to give bright sparks and most powerful shocks, and exhibit all the phenomena of voltaic electricity. Fig. 72 represents a very powerful arrangement of this kind."

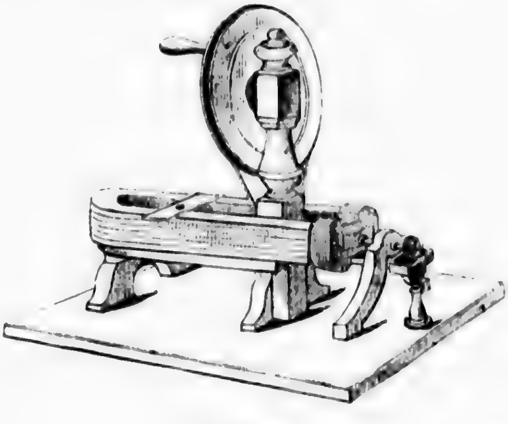


Fig. 72.

"When two covered wires are twisted together or laid side by side for some distance, and a current transmitted through the one, a momentary electrical wave will be induced in the reverse direction, and on breaking connexion with the battery, a second single wave will become evident by the aid of the galvanoscope, in the same direction as that of the primary current."

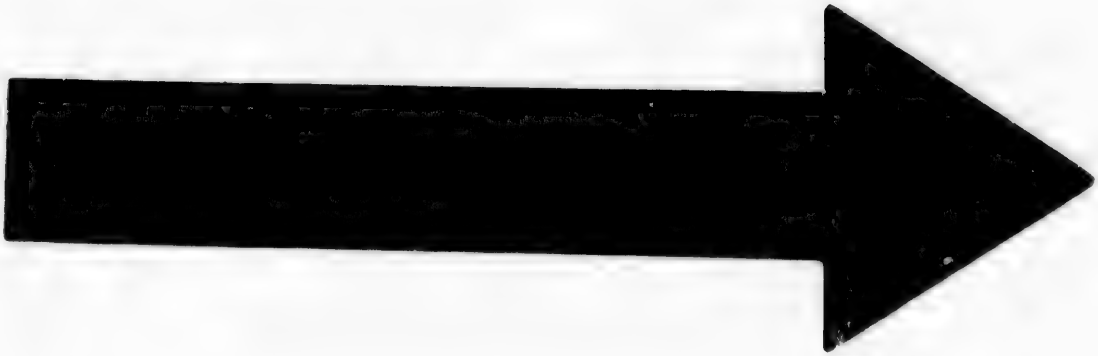
Lardner's Natural Philosophy.—Magnetism by induction.

(1630.) "*Soft iron rendered temporarily magnetic.*—If the poles of a magnet, this bar will itself become immediately magnetic. It will manifest a neutral line and two poles, that pole which is in contact with the magnet being of a contrary name to the pole which it touches. Thus if *A. B.*, Fig. 462, be the bar of soft iron which is brought in contact with the boreal pole *b.* of the magnet *a.b.*, then *A.* will be the austral and *B.* the boreal pole* of the bar of soft iron thus rendered magnetic by contact, and *E.* will be its equator, which, however, will not be the middle of the bar, but nearer to the point of contact."

Fig. 462.

"The state of the bar *A. B.* can be rendered experimentally manifest by any of the tests already explained. If it be rolled in iron filings, they will attach themselves in two tufts separated by an intermediate point which is

* The term austral is applied (by Lardner, 1656) to the pole of the magnet which points towards the north pole of the earth, and boreal to the opposite pole of the magnet which points to the south. The expressions so applied are perhaps likely to cause misunderstanding. In the case of volumetric electricity, we do not think the theory of two distinct forces or forms of force is, in the present state of scientific knowledge, unreasonable, although we are strongly of opinion that the facts will be found eventually not to support that theory. In applying the same theory or a modification of it to the case of magnetism there would not be, as it seems to us, the same reasonableness. The fact that a coil of wire which is conducting voltaic electricity displays the properties of a magnet, (as in De la Rive's apparatus, described by Fownes) and the fact, stated (Art. 1634) by Lardner himself, that if a magnate be divided each of the parts is a complete magnet in itself (*i.e.*, having an equator and two poles), taken together controvert such a supposition.



free from them; and if the test pendulum (1617)* be successively presented to different points of the bar, the varying intensity of the attraction will be indicated."

"If the bar *A. B.* be detached from the magnet, it will instantly lose its magnetic virtue."

(1631.) "It is not necessary, to produce these effects, that the bar of soft iron should be brought into actual contact with the pole of a magnet. It will be manifested, only in a less degree, if it be brought into proximity with the pole without contact. If the bar *A. B.* be presented at a small distance from the pole *b.*, it will manifest magnetism in the same manner; and if it be gradually removed from the pole, the magnetism it manifests will diminish in degree, until at length it wholly disappears."

(1634.) "It might be supposed, from what has been stated, that if a magnetic bar were divided at its equator, two magnets would be produced, one having austral and the other boreal magnetism, so that one of them would attract an austral and repel a boreal pole, while the other would produce the contrary attraction and repulsion. This, however, is not found to be the case. If a magnet be broken in two at its equator, two complete magnets will result, having each an equator at or near the centre, and two poles, austral and boreal; and if these be again broken, other magnets will be formed, each having an equator and two poles as before; and in the same manner, whatever be the number of parts, and however minute they be, into which a magnet is divided, each part will still be a complete magnet with an equator and two poles."†

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* A small ball of iron suspended by a fibre of silk. The ball is attracted or repelled out of the perpendicular when brought near to the respective poles of the magnet.

† We would suggest for consideration, whether sufficient prominence has been given to the full significance of this fact. The statement is definite and distinct, and when fully appreciated a clearer under-

(1638.) "*Effect of induction on hard iron or steel.*—If a bar of hard iron or steel be placed with its end in

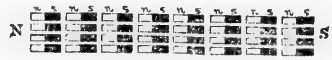

Fig. 26.

contact with a magnet in the same manner as has been already described with respect to soft iron, it will exhibit no magnetism; but if it be kept in contact with the magnet for a considerable length of time, it will gradually acquire the same magnetic properties as have been described in respect to bars of soft iron, with this difference, however, that having thus acquired them, it does not lose them when detached from the magnet as is the case with soft iron. Thus it would appear, that it is not literally true that a bar of steel when brought into contact with the pole of a magnet receives no magnetism, but rather that it receives magnetism in an insensible degree; for if continued contact impart sensible magnetism, it must be admitted that contact for shorter intervals must impart more or less magnetism, since it is the accumulation of the effects produced from moment to moment that the sensible magnetism manifested by continued contact is produced."

(1642.) "A red heat destroys the magnetism of iron. If a magnet, no matter how powerful, natural or artificial, be raised to a red heat, it will lose altogether its

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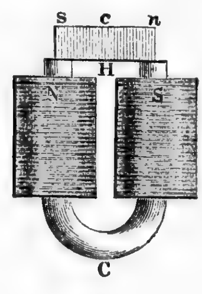
standing of the character of the magnet as being compounded of magnets is at once obtained; it becomes evident that the magnetic effect of the whole is the collective effect (or the sum of the effects) of the parts acting together, the effect of each particle augmenting the effects of the others. Hence the *molecular mode of the force* becomes at once distinctly apparent. The above illustration Fig. 26 is from Fownes' Manual of Chemistry.)

magnetic virtue.* The elevation of temperature and the molecular dilatation consequent upon it destroys the coercive force and allows the recombination of the magnetic fluid. When after such change the magnet is allowed to cool, it will continue divested of its magnetic qualities. These effects may, however, be again imparted to it by the process already mentioned."

Magnetization of Light and Dia-magnetism.

Encyclopedia Britannica, Chap. III., Sect. III.—"In the year 1845, Dr. Faraday discovered that when magnetic currents, or, as he expresses it, lines of magnetic force pass through certain bodies, they communicate to these bodies a certain magnetic condition, which, in transparent bodies, is analagous to rotatory double refraction and polorization, and which in other bodies is the reverse of that which takes place on iron, nickel, and some other metals.

If a parallelopiped *N. S. n. s.* of heavy flint glass, 2 inches square and ½ inch thick, and having no action on polarized light, is placed, as in the figure, on the poles *N. S.* of a powerful electro-magnet *N. C. S.*, and a strong galvanic current passed through it in the direction of *S. N.*, the glass will neither be attracted nor repelled, but is found to have received, while the current is pass-



* (1695.) "It appears that a magnetic bar when raised to a red heat does not lose its magnetism suddenly at that temperature." And, when plunged into boiling water and retained there for ten minutes, it loses a part of its magnetism, and if again replunged another portion, and so on, but still retaining a portion after seven or eight immersions.

ing through it, such a structure*, resembling that of quartz and certain fluids, as *to turn the plane of a polarized ray* in the same direction as the current. If the polarized ray is transmitted through the upper and under faces *H. G.* no effect whatever is produced. The rotation of the plane of polarization is from *left to right* when the ray enters the face *s. n.* and the observer looks into the face *n. s.*, and from *right to left* when the ray enters *n. s.*, and the observer looks into *s. n.* This is a very remarkable fact, as the direction of rotation is the same in rock-crystal and other bodies through whatever side the light enters.

The intensity of the rotatory-force depends upon the strength of the galvanic current, and upon the length of the piece of glass. When the ray, by reflections at *n.* and *s.* was made to pass *three* or *five* times through the length *n. s.* of the glass, the effect was increased three or five times, just as in rock-crystal it is increased by increasing the thickness of the plate."

Faraday's Biography, by Professor Tyndall.†

Page 84. "He showed that when a polarized ray passed through his heavy glass in a direction parallel to the magnetic lines of force, the relation is a maximum, and that when the direction of the ray is at right angles to the lines of force, there is no rotation at all. He also proved that the amount of the rotation is proportional to

* It is not quite apparent whether Sir D. Brewster means by this statement that an alteration or modification in the arrangement of the material particles of the substance takes place in it whilst under the influence of the magnet; supposing the expression of such supposition to be intended, it is not, we opine, supported by the evidence of the experiment. On the contrary, the fact of the immobility of the particles in the solid glass is opposed to the acceptance of such supposition; and, moreover, it is a reasonable inference that any such structural alteration in the matter of the substance would be directly cognizable in other ways, and it is not shown that such structural alteration has been cognized in other ways.

† 'Faraday as a discoverer.'

the length of the diamagnetic through which the ray passes. He operated with liquids and solutions. Of aqueous solutions he tried 150 and more, and found the power in all of them. He then examined gases; but here all his efforts to produce any sensible action on the polarized beam were ineffectual. He then passed from magnets to currents, enclosing bars of heavy glass, and tubes containing liquids and aqueous solutions within an electro-magnetic helix. A current sent through the helix caused the plane of polarization to rotate, and always *in the direction of the current.* The rotation was reversed when the current was reversed. In the case of magnets, he observed a gradual, though quick, ascent of the transmitted beam from a state of darkness to its maximum brilliancy when the magnet was excited. In the case of currents, the beam attained *at once* its maximum. This he showed to be due to *the time* required by the iron of the electro-magnet to assume its full magnetic power, which time vanishes when a current, without iron, is employed. 'In this experiment,' he says, 'we may, I think, justly say that a ray of light is electrified, and the electric forces illuminated.' In the helix, as with the magnets, he submitted *air* to magnetic influence 'carefully and anxiously,' but could not discover any trace of action on the polarized ray."

Page 90. "Before the pole of an electro-magnet, he suspended a fragment of his famous heavy glass: and observed that when the magnet was powerfully excited the glass fairly retreated from the pole. It was a clear case of magnetic *repulsion.* He then suspended a bar of the glass between two poles; the bar retreated when the poles were excited, and set its length *equatorially* or at right angles to the line joining them. When an ordinary magnetic body was similarly suspended, it always set *axially,* that is, from pole to pole. Faraday called those bodies which were repelled by the poles of a magnet, dia-magnetic bodies."

Page 91. "Soon after he had commenced his researches on dia-magnetism, Faraday noticed a remarkable phenomenon which first crossed my own path in the following way: In the year 1849, while working in the cabinet of my friend, Professor Knoblauch, of Marburg, I suspended a small copper coin between the poles of an electro-magnet. On exciting the magnet, the coin moved towards the poles and then suddenly stopped, as if it had struck against a cushion. On breaking the circuit, the coin was repelled, the revulsion being so violent as to cause it to spin several times round its axis of suspension. A *silbergroschen* similarly suspended exhibited the same deportment. For a moment I thought this a new discovery; but on looking over the literature of the subject, it appeared that Faraday had observed, multiplied, and explained the same effect during his researches on dia-magnetism. His explanation was based upon his own great discovery of magneto-electric currents. The effect is a most singular one. A weight of several pounds of copper may be set spinning between the electro-magnetic poles; the excitement of the magnet instantly stops the rotation. Though nothing is apparent to the eye, the copper, if moved in the excited magnetic field, appears to move through a viscous fluid; while, when a flat piece of the metal is caused to pass to and fro like a saw between the poles, the sawing of the magnetic field resembles the cutting through of cheese or butter. This virtual *friction* of the magnetic field is so strong, that copper, by its rapid rotation between the poles, might probably be fused. We may easily dismiss this experiment by saying that the heat is due to the electric currents excited in the copper. But so long as we are unable to reply to the question, 'What is an electric current?' the explanation is only provisional. For my own part, I look with profound interest and hope on the strange action here referred to."

Magnetic Curves.

Lardner's Natural Philosophy.

1615. "The neutral line and the varying attraction of the parts of the surface of the magnet which it separates may be manifested experimentally as follows: Let a magnet, whether natural or artificial, be rolled in a mass of fine iron filings. They will adhere to it, and will collect in two tufts on its surface, separated by a space upon which no filings will appear. The thickness with which the filings are collected will increase as the distance from the space which is free from them is augmented.

This effect as exhibited by a natural magnet of rough and irregular form, is represented in Fig. 456; and as exhibited by an artificial magnet in the form of a regular rod or cylinder whose length is considerable as compared with its thickness, is represented in Fig. 457; the equator being represented by *E. Q.*, and the poles by *A.* and *B.*

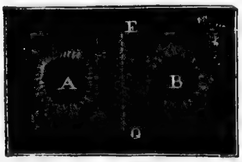


Fig. 456.

(1616.) "*Experimental illustration of the distribution of the magnetic force.*—The variation of the attraction of different parts of the magnet may also be illustrated as follows. Let a magnet, whether natural or artificial, be placed under a plate of glass or a sheet of paper, and let iron filings be scattered on the paper or glass over the magnet by means of a sieve, the paper or glass being gently agitated so as to give free motion to the particles.

Fig. 457.

They will be observed to effect a peculiar arrangement, corresponding with and indicating the neutral line or equator and the poles of the magnet, as represented in

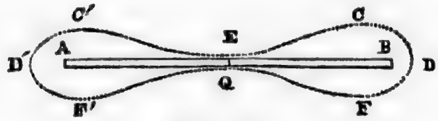
Fig. 458, where *E. Q.* is the equator, and *A.* and *B.* the poles of the magnet."

Fig. 458.

(1617.) "*Varying intensity of magnetic force indicated by a pendulum.*—The varying intensity of the attraction of different parts of the surface of the magnet may be ascertained by presenting such surface to a small ball of iron suspended by a fibre of silk so as to form a pendulum. The attraction of the surface will draw this ball out of the perpendicular to an extent greater or less, according to the energy of the attraction. If the equator of the magnet be presented to it, no attraction will be manifested, and the force of the attraction indicated will be augmented according as the point presented to the pendulum is more distant from the equator and nearer to the pole."

(1618.) "*Curve representing the varying intensity.*—This varying distribution of the attractive force over the surface of a magnet may be represented by a curve whose distance from the magnet varies proportionally to the intensity of this force. Thus, if, in Fig. 459, *E. Q.* be the equator and *A.* and *B.* the poles of the magnet, the curve *E. C. D. F.* may be imagined to be drawn in

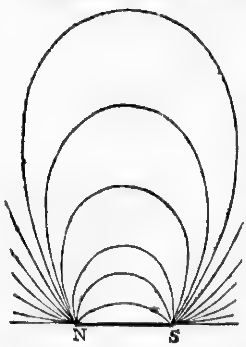
such a manner that the distance of its several parts from the bar *E. B.* shall be everywhere proportional to the



Fig, 459.

attractive force of the one pole, and a similar curve *E. C′. D′. F′.* will in like manner be proportional to the varying attractions of the several parts of the other pole. These curves necessarily touch the magnet of the equator *E. Q.*, where the attraction is nothing, and they recede from it more as their distance from the equator increases."

Encyclopedia Britannica, Chapter VIII.



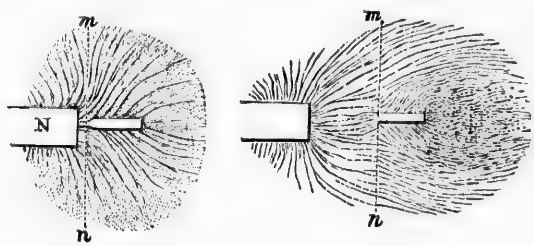
Sect. III. "The general form of the magnetic curves is shown in Fig. 49, where they are seen converging to the two poles *N.* and *S.* of the magnet *N. S.*, and changing their form with their distance from the magnet.

We have already stated that iron filings, arranged by the action of a powerful magnet, afford the finest experimental illustration of the magnetic curves. The best way to do this is to stretch a sheet of paper tightly over a wooden frame, and place it horizontally immediately above a powerful magnet lying on the table. Fine iron filings are now to be shaken through a gauze bag upon the surface of the paper. When the filings are thrown into agitation by gently tapping upon the paper frame, they will dispose themselves into regular lines, stretching from one pole of the magnet to the other, and following the course of the magnetic curves and exhibiting them

beautifully to the eye. This effect is shown in the annexed Fig. 50, where *N.* and *S.* are the poles of the magnet *N. S.*, *m.n.* being the mean line where no filings adhere. The same arrangement is also produced when the magnet is held above the paper containing the filings.

Fig. 50.

In the case of induced magnetism, the steel filings arrange themselves in curves round the iron on which the magnetism is induced, as shown in Fig. 51, where the small bar of iron is in contact with the north pole *N.* of a magnet, *m. n.* being the mean line which separates the two opposite actions of the little iron bar. When the little bar of iron is placed at a distance from the magnet *N.*, as in Fig. 52, the filings arrange themselves as in that figure, *m. n.* being the mean line as before."*



Lardner's Natural Philosophy.

(1752.) "*The electrophorus.*—A small charge of free electricity may by the agency of induction be made to produce a charge of indefinite amount, which may be imparted to any insulated conductor. This is effected

* For further illustrations of magnetic curves, see Appendix.

by the electrophorus, an instrument consisting of a circular cake, composed of a mixture of shellac, resin, and Venice turpentine, cast in a tin mould, *A. B.*, Fig. 493. Upon this is laid a circular metallic disc *C.*, rather less in diameter than *A. B.*, having a glass handle.

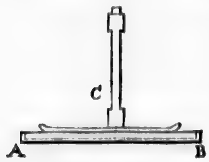


Fig. 493.

Before applying the disc *C.* the resinous surface is electrified negatively by striking it several times with the fur of a cat. The disc *C.* being then applied to the cake *A. B.*, and the finger being at the same time pressed upon the disc *C.* to establish a communication with the ground through the body of the operator, a decomposition takes place by the inductive action of the negative fluid on the resin. The negative fluid escapes from the disc *C.* through the body of the operator to the ground, and a positive charge remains, which is prevented from passing to the resin partly by the thin film of air which will always remain between them—even when the plate *C.* rests upon the resin—and partly by the non-conducting virtue of the resin.

When the disc *C.* is thus charged with positive electricity, kept latent on it by the influence of the negative fluid on *A. B.*, the finger being previously removed from the disc *C.*, let it be raised from the resin and the electricity upon it, before dissimulated, will become free, and may be imparted to any insulated conductor adapted to receive it.

The charge of negative electricity remaining undiminished on the resin *A. B.*, the operation may be indefinitely repeated; so that an insulated conductor may then be charged to any extent, by giving to it the electric fluid drop by drop thus evolved on the disc *C.* by the inductive action of *A. B.*"

Keeping in mind the relationship of the several physical forces as 'forms' or 'modes' of the one primary force,

..the significance of the result thus obtained by the inductive action of the electrophorus, in connection with the other observed facts of volumetric electricity, may be left to the attentive consideration of the reader without further comment than to note that herein we have a mode of disturbance by which a continuous and inexhaustible supply of free force can be (and is) obtained; inexhaustible, because it consists in a conversion of latent into free force, which, being removed, is replaced from the common reservoir of force, into which, again, that quantity removed from the surface of the material body, must necessarily find its way, ... It is, therefore, a continuous circulation of force, which force in its circulation is capable of producing by its action, an unlimited amount of effect on material bodies; ... meaning thereby, an effect, in its extent and character, proportional to the quantity and intensity of the force, upon an unlimited quantity of matter.

Having now brought together, from the record, a sufficient number of the natural (observed) facts to illustrate the relationship of the several forms of force; it is desirable to particularly caution the reader with respect to the relation of matter and force, ... On the one hand, not to invest matter with imaginary properties which do not belong to it, and ... on the other hand, not to confound reasoning by doubting the reality of those properties and characteristics which do belong to matter, and things material, and which distinguish it from spirit and things spiritual.

In a scientific sense, *i.e.*, a correct sense, the meaning attached to matter should include all those things which we clearly recognize as belonging distinctly to matter *i.e.*, to *that* which is so-called), and should include nothing else; consequently the word 'matter' should be a collective expression for those properties and characteristics of which it consists; and therefore, to fully and correctly apprehend and describe all those properties

and characteristics which pertain to *matter*, is to give a comprehensive and correct definition of the word ‘matter.’ A dispute, controversy, or argument, as to certain of the properties alleged on the one side and questioned on the other, to belong to *matter*, is a dispute or an argument as to the correct definition of the word, and which definition, if shown to be incorrect or defective, may be amended accordingly. To deny the existence or reality of matter is simply folly; for why should not the word ‘matter’ be as good as any other word to denote those things or that class of things which must be denoted by some collective expression.

But if we are justified in the generalization with respect to the various physical forces which has been now put before the reader, the question then suggests itself, whether matter is not also referable to the primary force; or, in other words, whether matter is not itself a form of force, differing only more essentially from each and all the other forms of force, known to us, than those other forms of force differ from each other.

The supposition being entertained, accordingly, that *matter* is, humanly speaking, a distinct fundamental form of force, differing from that fundamental or collective form which we have denominated Electric Force.

The relationship may be thus formulated:

Force.	Electric Force Matter.......	The various descriptions of compound matter, *i.e.*, the chemical varieties of matter.

Compound Matter Electric Force....	The various conditions or states of matter, *e.g.*, the solid, fluid, or gaseous condition; ... a state of motion, or, restraint from motion, &c.

If we adopt this as a theory, or assume it to be an approximately correct explanation, we shall find therein cause to look upon *matter* as particularly connected with

ourselves, because entering into our organization as human beings, and appearing to our material senses to constitute *nature*. (Constituting, in fact, that which we *term* nature.) But, viewing the subject in this relationship, we are able to perceive that . . in a spiritual (or universal) sense . . we ought to consider *matter*, (*i.e.*, the material world) as comparatively artificial, by which we mean, as a restricted and limited form of that which is in its primary nature unrestricted and unlimited. Or, to express the same meaning otherwise, we ought to consider that those forces . . . which in a universal or celestial sense may be termed, in their primary condition, *natural* . . . are in the material world materialized and adapted to a particular and limited purpose . . . that purpose including a special restriction within certain definite limits and boundaries, of forces which are in their primary nature unrestricted and unlimited. Both are actually existent . . . the spiritual and the material . . . and both are consequently real. It would not, therefore, be correct to speak of the one as the shadow of the other; nevertheless, the material reality being derived from the spiritual, and being limited and restricted to certain conditions, the material reality does *represent* the shadow or the reflected image (so to speak) of the unlimited spiritual reality of which it is (may be said to be) a modification. We believe that the form of self-deception or prejudice called 'materialism' has now (in a greater or lesser degree) so strong a hold on the minds of even educated persons that it will, at first, appear to many like stating a paradox to make the assertion that the actual inter-relation of spiritual and natural reality is such that the material world (*i.e.*, matter in all its forms constituting that which we call *nature*,) occupies a relationship to the spiritual world somewhat akin to that which the shadow bears to the substance. We believe that to many this will be calling upon them to reverse their preconceived notions about natural reality; but it necessarily follows that such is the char-

acter of the actual relationship between 'material' and 'spiritual' reality, if the explanation we have given of the nature of the physical forces and of matter, be accepted as approximately correct, . . . and we say that, by the rules of sound science, that explanation must necessarily be so accepted.

Note.—To those persons who are desirous to correctly understand this relationship and who find a difficulty in following the argument, we wish to point out the necessity of carefully examining, in the first instance, the precise value of the meaning which they themselves attach to the most prominent terms here made use of, and especially to the words 'nature' and 'matter.' The word 'matter' having been defined, the entire argument or explanation of the subject might be very well put in the form of a definition of the word 'nature,' or, on the other hand, the meaning of the word 'nature' may be restricted and limited to that material sense in which it is usually understood and used, but if so, then, let those who use it in that sense be mindful that its meaning is so restricted, viz., that it is used in a material sense only and not in a general or absolute sense.——

It may assist some persons, perhaps, to suggest the use of the compound terms 'Material-Nature' and 'Spiritual-Nature.' It may be then understood that 'Material-Nature' belongs to a part of creation having a special and distinct purpose; and being, therefore, an adaptation, in which the properties and characteristics of the elementary parts are limited and restricted by special and distinct laws framed expressly for the uniform and harmonious regulation of those parts under the limiting and special conditions to which the material world was to be subjected, it may be apprehended without much difficulty that 'Material-Nature' is, in a more general or spiritual sense, artificial; because it is an adaptation having a special and limited character; nevertheless, be it carefully noted that, all the parts of *this distinct part*

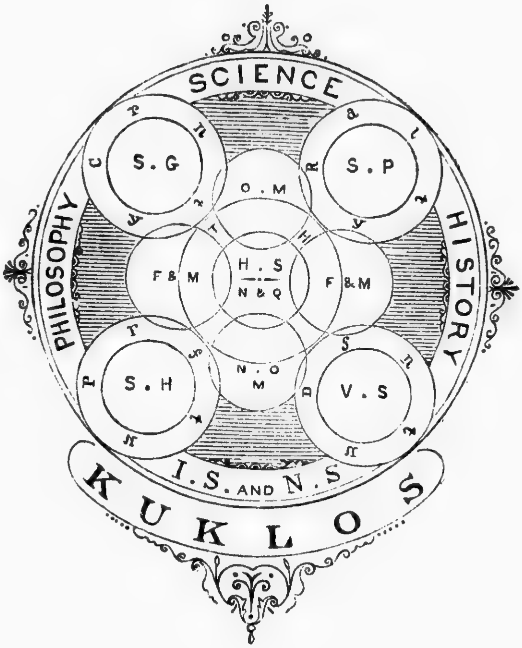
of creation (*i.e.*, of the material world, or of 'nature' as usually understood,) are real and true, not only in a material, but also in a spiritual sense.

The plan upon which this distinct part of creation is arranged and the laws by which it is regulated... although arbitrary in the sense of limiting and restricting the elementary and compounding parts to the conditions assigned them in the plan, ... are not to be considered arbitrary in any other sense; there is no reason whatever to infer, and it is not to be inferred, that the reality and truth of the material world are not in harmony with, or that they are not a part of, the reality and truth of the spiritual world.——

We come now to the conclusion of a work which commenced with a reference to the author of the 'great instauration.' The purpose of this our undertaking is in a great measure the same as that which he had in view, namely, to separate sound and wholesome knowledge from the pernicious influence of that corrupt philosophy and unsound knowledge with which it was then, as it is now again becoming, more and more, contaminated. Much of his work was almost necessarily, and most advantageously, occupied in teaching the method of scientifically classifying knowledge... *i.e.*, of separating and arranging, into an available and useful form, the heterogeneous and disorderly collection of knowledge which at that time obtained. For a long time past this part of Bacon's system has been fully in use, and it is now well understood and practised; therefore, since it is needless for us to teach what is already well known, the two works will necessarily appear to differ very much in form. We believe, however, that the method adopted will be found on investigation to be essentially the same in both.

However this may be, we know, at least, that the present work has been undertaken and carried out in the same spirit in which we believe that his was accom-

plished, and we have the same hope and desire that our work will commend itself to the acceptance of those for whose benefit it is intended, which he expressed and doubtless felt. We will, therefore, conclude by expressing, in his words, feelings which we share with him, and by dedicating, in his words, this our work, in all humility, to Him without whose aid and approval the wisdom of the cleverest man is but foolishness. . . May Thou, therefore, O Father, who gavest the light of vision as the first fruit of creation, and who hast spread over the fall of man the light of Thy understanding as the accomplishment of Thy works, guard and direct this work, which issuing from Thy goodness, seeks in return Thy glory! When Thou hadst surveyed the works which Thy hands had wrought, all seemed good in Thy sight, and Thou restedst. But when man turned to the works of his hands, he found all vanit and vexation of spirit and experienced no rest. If, however, we labour in Thy works, Thou wilt make us to partake of Thy vision and Sabbath; we, therefore, humbly beseech Thee to strengthen our purpose, that Thou mayst be willing to endow Thy family of mankind with new gifts, through our hands, and the hands of those in whom Thou shalt implant the same spirit.


SCIENCE
PHILOSOPHY
HISTORY
S.G
S.P
O.M
F&M
H.S
N&Q
F&M
S.H
N.O
M
V.S
I.S. AND N.S
KUKLOS

MAGNETISM.

Encyclopedia Britannica, Chap VII., Sec. III., Art. Magnetism.—Dr. Roget gives the following interesting account of the phenomena which take place by continuing to agitate the filings when they are arranged, as in Fig. 53:—

"By continuing to tap upon the paper," says he, "the filings arrange themselves still more visibly into separate lines; but here a curious and perhaps unlooked for phenomenon presents itself. The lines gradually move and recede from the magnet, appearing as if they were repelled instead of attracted, as theory would lead us to expect. This arises from the circumstance, that each particle of iron, or cluster of particles, is thrown up into the air by the shaking of the paper, and, while unsupported, immediately turns on its centre, and acquires a position more or less oblique to the plane of the paper. This is shown in Fig. 53, in which *M.* represents a section of the magnet, *P. P.* a section of the paper, and *f. f.* the position of the filaments of iron thrown up into the air. The end of each filament nearest to the magnet is thus turned a little downwards, and the filament falls upon the paper at a point a little more distant than that which it before occupied; and thus, step by step, it moves farther and farther from the magnet, till it reaches the edge of the paper, and falls off."

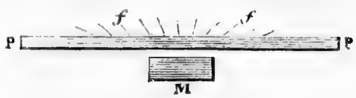


Fig. 53.

"When the magnet, instead of being beneath the paper, is held above it, the effect is just the reverse. In

this latter case, the lower ends of the filaments having a tendency to turn towards the magnet, the filings gradually collect under it, when made to dance by the vibrations of the paper, instead of falling outwards as they did before. This will be seen from Fig. 54, where the letters have the same indications as in Fig. 53."

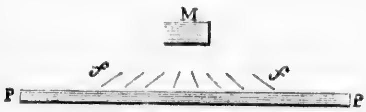


Fig. 54.

"A different set of magnetic curves is produced when two similar poles, for example, two north poles, as shown in Fig. 55, (Pl. 11,) are placed near each other. These curves are called *divergent* curves, and may be exhibited by iron filings like the convergent ones.

Dr. Roget has given the following expeditious method of delineating a great number of magnetic curves, related to the same distance between two magnetic poles. He describes from each pole *N. S.*, Fig. 56, as centres, the equal circles or semi-circles *A. A.*, *B. B.*, with as large a radius as the paper will allow; and dividing the axis produced till it meets both circles, he marks off, on the circumferences of both circles, the points where they are cut by perpendiculars from these points of division; then drawing radii from the centre of each circle to the divisions of the respective circumferences, the mutual intersections of these radii will give different sets of points indicating the form of the magnetic curves which pass through them. Fig. 56, (Plate 11.) These curves are, in the present case, composed of a succession of diagonals of the lozenge shaped interstices formed by the intersecting radii, as shown from *convergent* curves in the upper half of the Figure. In the case of *divergent* curves, in Fig. 55, (Pl. 11,) we must take the other diagonals of the lozenge shaped intervals between the intersecting radii; that is, the diagonals which cross those constituting the convergent curves. This is shown in the lower half of the Figure."

PLATE 11.

Fig. 55.

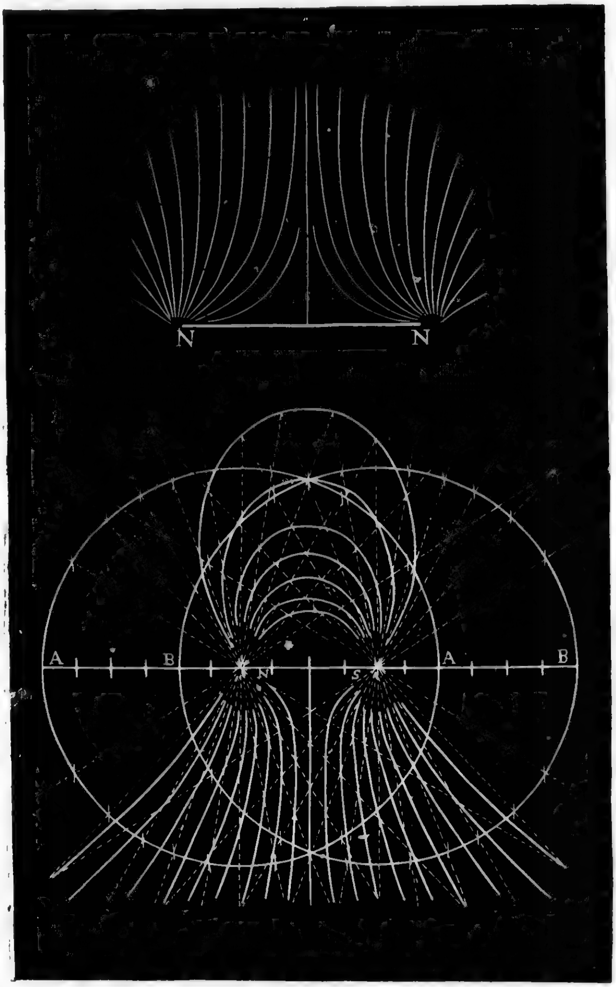


Fig 56

MAGNETIC CURVES.

SECT. II.—*On the mutual action of Magnets.*

When a needle is exposed to the combined action of two magnets, as shown in the annexed Figure, the phenomena, though capable of calculation by the principles already explained, are extremely perplexing and complicated when studied experimentally. Dr. Robison, who first discovered and explained these phenomena, has given such an interesting account of them, that we shall make use of his description of the phenomena, leaving the explanation of them to the next section on magnetic curves.

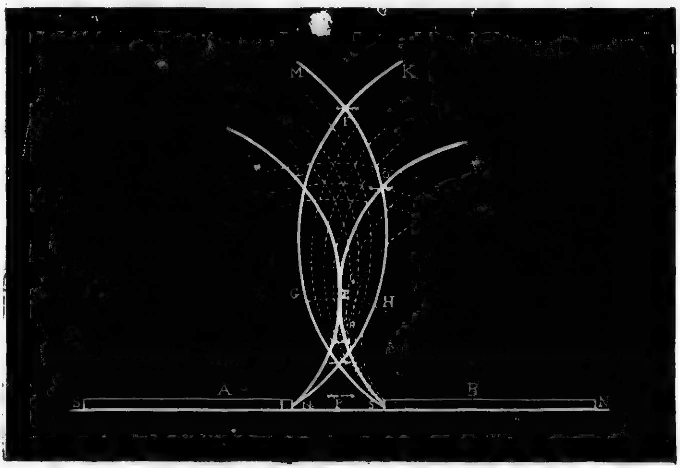


Fig. 46.

"Two large and strong magnets, *A.* and *B.*, were placed with their dissimilar poles fronting each other, and about three inches apart. A small needle, supported on a point, was placed between them at *D.*, and it arranged in the same manner as the great magnets. Happening to set it off to a good distance on the table, as at *F.*, he was surprised to see it immediately turn round on its point, and arrange itself nearly in the opposite direction. Bringing it back to *D.* restored it to its former

position. Carrying it gradually out along *D. F.*, perpendicular to *N.S.*, he observed it to become sensibly more feeble, vibrating more slowly; and when in a certain point, *E.*, it had no polarity whatever towards *A.* and *B.*, but retained any position that was given it. Carrying it farther out, it again acquired polarity to *A.* and *B.*, but in the opposite direction; for it now arranged itself in a position that was parallel to *N. S.*, but its north pole was next to *N.* and its south pole to *S.*" * * *

APPENDIX TO ELECTRICAL INDUCTION.

See Page 139.

From *Lardner's Natural Philosophy.*

(1745.) "*Reciprocal Inductive Effects of two Condensers.*—If a conductor *A.* communicating with the ground be placed near another conductor *B.* insulated and charged with a certain quantity of electricity *E.*, a series of effects would ensue by the reciprocal inductive power of the two conductors, the result of which will be augmented in a certain proportion, depending on the distance between the two conductors through which the inductive force acts."

(1747.) "The electricity developed in such cases on the conductor *A.* is subject to the anomalous condition of being incapable of passing away though a conductor be applied to it. In fact, the conductor *A.* in the preceding experiment is supposed to be connected with the earth by conducting matter, such as a chain, metallic column, or wire. Yet the charge of electricity does not pass to the earth as it would immediately do if the conductor *B.* were removed.

In like manner, all that portion of the positive fluid *P.* which is developed on *B.* by the inductive action of *A.* is held there by the influence of *A.* and cannot escape even if the conductors be applied in contact with it."

(1748.) "*Free electricity.*—Electricity, therefore, which is developed independently of induction, or which, being first developed by induction, is afterwards liberated from the inductive action, is distinguished as *free* electricity. In the process above described, that part of the charge *P.* of the conductor *B.* which is expressed by *E.* and which was imparted to *B.* before the approach of the conductor *A.*, is *free*, and continues to be free after the approach of *A.* If a conductor connected with the earth be brought into contact with *B.*, this electricity *E.* will escape by it; but all the remaining charge of *B.* will remain, so long as the conductor *A.* is maintained in its position. If, however, *E.* be discharged from *B.* the charge which remains will not be capable of retaining in the dissimulated state so great a quantity of negative fluid on *A.* as before. A part will be accordingly set free, and if *A.* be maintained in connection with the ground it will escape. If *A.* be insulated it will be charged with it still, but in a free state.

If this free electricity be discharged from *A.* the remaining charge will not be capable of retaining in the latent state so large a quantity of positive fluid on *B.* as previously, and a part of what was dissimulated will accordingly be set free, and may be discharged.

In this manner, by alternate discharges from the one and the other conductor, the dissimulated charges may be gradually liberated and dismissed, without removing the conductors from one another or suspending their inductive action."

ELECTRICITY.

From *Fownes' Manual of Chemistry.*

"If glass, amber, or sealing-wax be rubbed with a dry cloth, it acquires the power of attracting light bodies, as feathers, dust or bits of paper; this is the result of a"

"new and peculiar condition of the body rubbed, called electrical excitation.

If a light downy feather be suspended by a thread of white silk, and a dry glass tube, excited by rubbing, be presented to it, the feather will be strongly attracted to the tube, adhere to its surface for a few seconds, and then fall off. If the tube be now excited anew, and presented to the feather, the latter will be strongly repelled.

The same experiment may be repeated with shellac or resin, the feather in its ordinary state will be drawn towards the excited body, and after touching, again driven from it with a certain degree of force.

Now let the feather be brought in contact with the excited glass, so as to be repelled by that substance, and let a piece of excited sealing-wax be presented to it; a degree of attraction will be observed far exceeding that exhibited when the feather is in its ordinary state. Or, again, let the feather be made repulsive for sealing-wax, and then the excited glass presented; strong attraction will ensue.

The reader will at once see the perfect parallelism between the effects described and some of the phenomena of magnetism; the electrical excitement having a two-fold nature, like the opposite polarities of the magnet. A body to which one kind of excitement has been communicated is attracted by another body in the opposite state, and repelled by one in the same state. The excited glass and resin being to each other as the north and south poles of a pair of magnetized bars.

To distinguish these two different forms of excitement, terms are employed, which, although originating in some measure in theoretical views of the nature of the electrical disturbance, may be understood by the student as purely arbitrary and distinctive: it is customary to call the electricity manifested by glass *positive* or *vitreous*, and that developed in the case of shellac, and bodies of the same class, *negative* or *resinous*. The kind"

of electricity depends in some measure upon the nature of the surface; smooth glass rubbed with silk or wool becomes ordinarily positive, but when ground or roughened by sand or emery, it acquires, under the same circumstances, a negative charge.

The repulsion shown by bodies in the same electrical state is taken advantage of to construct instruments for indicating electrical excitement and pointing out its kind. Two balls of alder-pith, hung by threads or very fine metal wires, serve this purpose in many cases; they open out when excited in virtue of their mutual repulsion, and show by the degree of divergence the extent to which the excitement has been carried.

Fig. 58.

Fig. 59.

A pair of gold leaves suspended beneath a bell-jar, and communicating with a metal cap above, constitute a much more delicate arrangement, and one of great value in all electrical investigations. These instruments are called electroscopes or electrometers; when excited by the communication of a known kind of electricity they show, by an increased or diminished divergence, the state of an electrified body brought into their neighbourhood.

One kind of electricity can no more be developed without the other than one kind of magnetism; the rubber and the body rubbed always assume opposite states, and the positive condition on the surface of a mass of matter is invariably accompanied by a negative state in all surrounding bodies."

The induction of magnetism in soft iron has its exact counterpart in electricity; a body already electrified disturbs or polarizes the particles of all surrounding substances in the same manner and according to the same law, inducing a state opposite to its own in the nearer portions, and a similar state in the more remote parts. A series of globes suspended by silk threads, in the manner represented, will each become electric by induction when a charged body is brought near the end of the series, like so many pieces of iron in the vicinity of a magnet, the positive half of each globe looking in one and the same direction, and the negative half in the opposite one. The positive and negative signs are intended to represent the states.

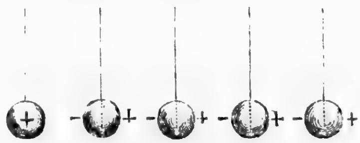


Fig. 60.

The intensity of the induced electrical disturbances diminishes with the distance from the charged body; if this be removed or discharged, all the effects cease at once.

So far, the greatest resemblance may be traced between these two sets of phenomena; but here it seems in a great measure to cease. The magnetic polarity of a piece of steel can awaken polarity in a second piece in contact with it by the act of induction, and in so doing loses nothing whatever of its power; this is an effect completely different from the apparent transfer or discharge of electricity constantly witnessed, which in the air and in liquids often gives rise to the appearance of a bright spark of fire. Indeed, ordinary magnetic effects comprise two groups of phenomena only, those namely of attraction and repulsion, and those of induction. But

in electricity, in addition to phenomena very closely resembling these, we have the effects of *discharge*, to which there is nothing analogous in magnetism*, and which takes place in an instant when any electrified body is put in communication with the earth by any one of the class of substances called conductors of electricity; all signs of electrical disturbance then ceasing.

These conductors of electricity, which thus permit discharges to take place through their mass, are contrasted with another class of substances called non-conductors or insulators. The difference, however, is only one of degree, not of kind; the very best conductors offer a certain resistance to the electrical discharge, and the most perfect insulators permit it to a small extent. The metals are by far the best conductors; glass, silk, shellac, and dry gas, or vapor of any sort, the very worst; and between these there are bodies of all degrees of conducting power.

Electrical discharges take place silently and without disturbance in good conductors of sufficient size. But if the charge be very intense, and the conductors very small or imperfect, from its nature, it is often destroyed with violence.

When a break is made in a conductor employed in effecting the discharge of a highly excited body, disruptive or spark-discharges, so well known, takes place across the intervening air, provided the ends of the conductors be not too distant. The electrical spark itself presents many points of interest in the modifications to which it is liable.

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* May not the magneto-electric machine (page 168), wherein the poles of the armature in which the magnetism is induced, are suddenly and continually reversed in front of the magnet, be considered as exhibiting a succession of discharges (of molecular or magnetic electricity)? The wire, in that case, which is coiled an immense number of times around the magnet, would represent, or be analogous to, the condenser and conductor of the volumetric electricity.

The time of transit of the electrical wave through a chain of good conducting bodies of great length is so minute as to be altogether inappreciable to ordinary means of observation. Professor Wheatstone's very ingenious experiments on the subject give, in the instance of motion through a copper wire, a velocity approaching that of light.

Electrical excitation is *apparent* only upon the surfaces of bodies, or those portions directed towards other objects capable of assuming the opposite state. An insulated ball charged with positive electricity, and placed in the centre of the room, is maintained in that state by the inductive action of the walls of the apartment, which immediately become negatively electrified; in the interior of the ball there is absolutely no electricity to be found, although it may be constructed of open metal gauze, with meshes half an inch wide. Even on the surface the distribution of electrical force will not always be the same; it will depend upon the figure of the body itself, and its position with regard to surrounding objects. The polarity will always be highest in the projecting extremities of the same conducting mass, and greatest of all when these are attenuated to points, in which case the inequality becomes so great that discharge takes place to the air, and the excited condition cannot be maintained.

THE ELECTRICAL MACHINE AND CONDENSER.

The ordinary plate machine, Fig. 62, is thus described by Fowne's: "Another form of the electrical machine consists of a circular plate of glass moving upon an axis, and provided with two pairs of cushions or rubbers, attached to the upper and lower parts of the wooden frame, covered with amalgam, between which the plate moves with considerable friction. An insulated conductor, armed as before with points, discharges the plate

as it turns, the rubbers being at the same time connected with the ground by the woodwork of the machine, or by a strip of metal."

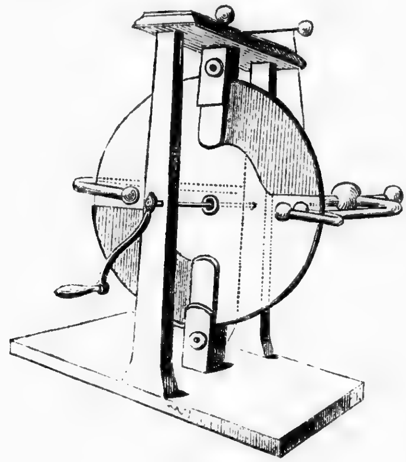


Fig. 62.

The most simple modification of the electrical machine is the electrophorus already mentioned (page 180); another form of (the electrophorus) is shown at Fig. 11, contrived by Mr. John Phillips, of York, in which the resinous disc is perforated and brass wires (*c. c. c.* in the Fig.) are inserted through the bottom plate and have their ends level with the surface of the resin, so that when the cover is put on, communication between it and the ground is established through the wires. "With ordinary excitation this instrument will yield loud flashing sparks two inches long or more, and speedily charge considerable jars. The

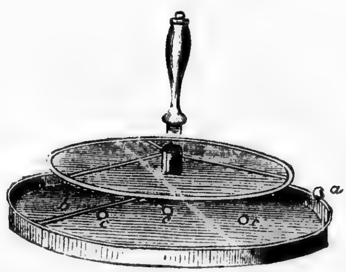


Fig. 11.

cover can be easily charged and discharged fifty or a hundred times in a minute, by merely setting it down and lifting it up as fast as the operator chooses, or the hand can work. In charging a jar or plate, I place one knob of the connecting rod near the insulated surface of the jar or plate, and the other some inches above the cover; then the cover being alternately lifted up and set down, the jar is very quickly charged."

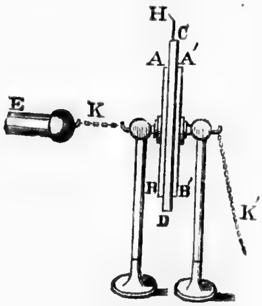
THE CONDENSER AND LEYDEN JAR.

(From *Lardner's Natural Philosophy.*)

(1759.) "The inductive principle which has supplied the means in the case of the condenser of detecting and examining quantities of electricity so minute and so feeble as to escape all common tests, has placed in the Leyden jar, an instrument at the disposal of the electrician, by which artificial electricity may be accumulated in quantities so unlimited as to enable him to copy in some of its most conspicuous effects the lightning of the clouds.

To understand the principle of the Leyden jar, which at one time excited the astonishment of all Europe, it is only necessary to investigate the effect of a condenser of considerable magnitude placed in connection, not with feeble but with energetic sources of electricity, such as the prime conductor of an electrical machine. In such case it would be evidently necessary that the collecting and condensing plates should be separated by a non-conducting medium of sufficient resistance to prevent the union of the powerful charges with which they would be invested. Let *A. B.*, Fig. 499, represent the collecting plate of such a condenser, connected by a chain *K.* with the conductor *E.* of an electric machine; and let *A'. B'.* be the condensing plate connected by a chain *K.* with the

"ground. Let $C. D.$ be a plate of glass interposed between $A'. B'.$ and $A. B.$



Let $e.$ express the quantity of electricity with which a superficial unit of the conductor $E.$ is charged. It follows that $e.$ will also express the *free* electricity on every superficial unit of the collecting plate $A. B.$, and of the total charge on each superficial unit of $A. B.$ free and dissimulated, be expressed by $a.$, we shall, according to what has been already explained, have

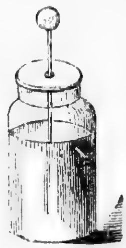
$$a = \frac{e}{1 - m^2}$$

"When the machine has been worked until $e.$ ceases to increase, the charge of the plates will have attained its maximum. Let the chains $K.$ and K' be then removed, so that the plates $A. B.$ and $A.' B.'$ shall be insulated, being charged with the quantities of electricity of contrary names expressed by $E.$ and $E.'$"

"In order to divest these principles of whatever is adventitious, and to bring their general character more clearly into view, we have here presented them in a form somewhat different from that in which they are commonly exhibited in electrical experiments. The phenomenon which has just been explained, consisting merely in the communication of powerful charges of electricity of contrary kinds, on the opposite faces of glass or other non-conductor, by means of metal maintained in contact with the glass, it is evident that the form of the glass and of the metal in contact with it, have no influence on the effects. Neither has the thickness or volume of the metal any relation to the results. Thus the glass, whose opposite faces are charged, may have the form of a hollow cylinder or sphere, or of a common flask or bottle, and"

"the metal in contact with it need not be massive or solid plates, but merely a coating of metallic foil.

1760. *The Leyden Jar.*—In experimental researches, therefore, the form which is commonly given to the glass, with a view to develop the effects, is that of a cylinder or jar *A. B.* Fig. 500, having a wide mouth and a flat bottom. The shaded part terminating at *C.* is a coating of tinfoil placed on the bottom and sides of the jar, a similar coating being attached to the corresponding part of the interior surface. A metallic rod, terminating in a ball *D.*, descends into the jar, and is jointed (?) in contact with the inner coating." (The flattened base of the rod rests upon the inner coating at the bottom of the jar.)

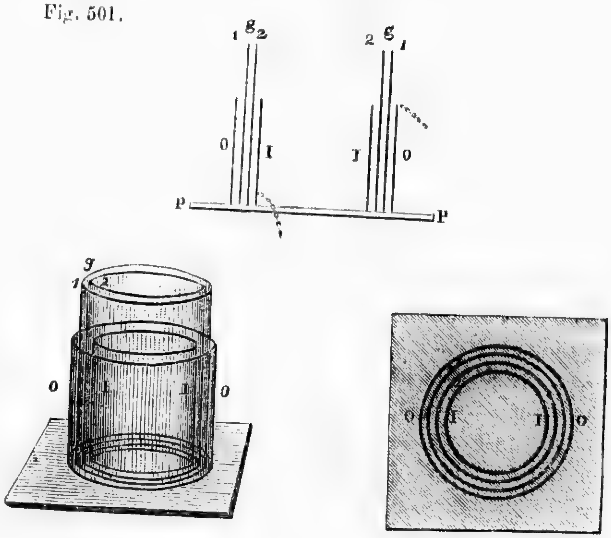


1763. "*Experimental proof that the charge adheres to the glass and not to the coating.*—The electricity with which the jar is charged in this case resides, therefore, on the glass, or on the conductor by which it passes to the glass, or is shared by these.

To determine where it resides, it is only necessary to provide means of separating the jar from the coating after it has been charged, and examining the electrical state of the one and the other. For this purpose let a glass jar be provided, having a loose cylinder of metal fitted to its interior, which can be placed on it or withdrawn from it at pleasure, and a similar loose cylinder fitted to its exterior. The jar being placed on the external cylinder, and the internal cylinder being inserted in it, let it be charged with electricity by the machine in the manner already described. Let the internal cylinder be then removed, and let the jar be raised out of the external cylinder. The two cylinders being then tested by an electroscopic apparatus, will be found in their natural state. But if an electroscope be brought within the influence of the internal or external surface of the glass jar, it will betray the presence of the one or the other"

"species of electricity. If the glass jar be then inserted in another metallic cylinder made to fit it externally and a similar metallic cylinder made to fit it internally be inserted in it, it will be found to be charged as if no change had taken place. On connecting by metallic communication the interior with the exterior, the opposite electricities will rush towards each other and combine. It is evident, therefore, that the seat of the electricity, when a jar is charged, is not the metallic coating, but the surface of the glass under it."

Fig. 501.



We do not find any record of this very interesting and instructive experiment having been further pursued. The conclusion here stated does not appear to be demonstrated by the evidence, and it must, for the present at least, be considered questionable and possibly deceptive. By this gradually withdrawing one metallic cylinder at a time, the effect would be to *transfer* the electricity to the glass vessel by distributing it evenly over the surface thereof. For the purpose of obtaining more decisive

evidence the experiment may be thus followed:—(Fig. 501.) Let two loose cylinders of glass, open at both ends, represented at *g*. 1 and 2, in the figure, be placed upright, one inside the other, upon a plate of glass *P.*; and let two cylinders of metal, *I.* and *O.*, not so long as the glass cylinders, be also placed upright on the glass plate, one of them, marked *I.* in the fig., inside the smaller glass cylinder, and the other (metal cylinder), marked *O.*, outside the larger glass cylinder.

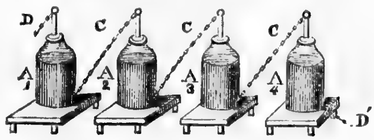
The apparatus being thus arranged, let either one of the metal cylinders be made to connect with the earth by a conducting chain attached to it, or in some other suitable manner, and let the other metal cylinder be then charged with electricity; after which; the chain or other connector may be detached. Either one of the glass cylinders may be now removed and tested by the electroscope. If it be found not to have brought with it any of the electricity, it may be replaced and the other glass cylinder may be removed and tested. Should it further appear that the second cylinder had likewise brought away none of the electricity, the first glass cylinder may be then also removed. If the distance between the two metal cylinders is but small and the charge considerable, the electricity will now pass through the air from the one to the other, and they will be thus discharged, but, on the one hand, the distance between the cylinders may be increased, or, the quantity of electricity supplied to the apparatus may be lessened, because a very slight charge would suffice to try the question.* On the supposition that the actual result has not been as yet experimentally ascertained, we opine that the electricity

* It is here intended for the cylinders to be close together so as for their sides to be almost in contact, but, we would suggest that, by taking cylinders differing considerably in size, so as to increase the distance between them, some other interesting questions might be in this way submitted to experiment. The material of which the cylinders are composed might be also varied.

(all of it) will be found, contrary to Dr. Lardner's conclusion, to remain with the metal cylinders.

Lardner's Natural Philosophy.

(1765.) "*Charging a series of Jars by Cascade.*—In charging a single jar, an unlimited number of jars, connected together by conductors, may be charged with very nearly the same quantity of electricity. For this purpose let the series of jars be placed on insulating stools as represented in Fig. 502, and let *C.* be metallic chains connecting the external coating of each jar with the internal coating of the succeeding one. Let *D.* be a chain connecting the first jar with the conductor of the machine, and *D'.* another chain connecting the last jar with the ground. The electricity conveyed to the inner coating of the first jar *A.* acts by induction on the external coating of the first jar, attracting the negative electricity to the surface, and repelling the positive electricity through



the chain *C.* to the inner coating of the second jar. This charge of positive electricity in the second jar acts in like manner inductively on the external coating of this jar, attracting the negative electricity there, and repelling the positive electricity through the chain *C.* to the internal coating of the third jar; and in the same manner the internal coating of every succeeding jar in the series will be charged with positive electricity, and its internal coating with negative electricity. If, while the series is insulated, a discharger be made to connect the inner coating of the first with the outer coating of the last jar, the opposite electricities will rush towards each other, and the series of jars will be restored to their natural state."

The word cascade, as used here to denote the move

ment or transference of the electricity from one jar to the next, belongs to the (material) fluid hypothesis of electricity and is an objectionable mode of expression. Our object, however, in quoting the above case just now, is to suggest that the evidence of this experiment is opposed to the theory of two electricities (or two kinds of electricity) . . . for, how is that theory to be reconciled with the fact here shown? namely, that positive electricity accumulated on the inside (or outside) surface of the one jar is directly connected by the conducting chain with negative electricity accumulated on the outside (or inside) surface of the next jar, and yet the supposed two electricities, having such a powerful attraction each for the other, remain separate and distinct! For example, if we suppose the outside charge of the jar marked *A.* 1, to be negative electricity, then, by the record, the inside charge of the jar *A.* 2, is positive electricity, and between these, communicating, with both of them, there is the conducting chain *C.*

The argument may suggest itself as a reply . . . Oh, as to that, . . if you suppose only *one* kind of electricity you are in precisely the same difficulty. But it is not so; . . electricity is communicated, we will suppose, to the interior coating of jar A 1, this having distributed itself over that interior surface acts by induction on the exterior surface, driving out the electricity over the conducting chain into the interior of the next jar, where it distributes itself and acts inductively on the surface of the exterior coating of that jar, as before, and so on. Now this is quite intelligible, because the fact has been established by observation of many other distinct cases that electricity has precisely such inductive action, and the same influence of the free electricity on the one surface, which drives out the electricity from the other surface, will evidently, being still free and active, prevent its return, (and this applies to the case of each jar.) It is true that no theoretical reason, based on other and

distinct facts, can be at present shown why electricity should thus act inductively, it is an observed property or influence belonging to that spiritual force, and which being known the explanation of the result is quite intelligible. We would remark, in conclusion, that this case, also, does not appear to have received that share of attention, from experimental investigators, which the very interesting and peculiar nature (so to speak) of the phenomenon invites and calls for.

MOLECULAR ELECTRICITY.

The Encyclopedia Britannica.

Voltaic Electricity. —— Sec. IV. *On the production of Light, Heat and Cold by Voltaic Electricity.* — *The Ignition of Wires.* — "It was in England, however, that the calorific and luminous effects of the pile were principally developed. In 1813, the immense battery of the Royal Institution, composed of 2000 couples, and exposing 28,000 square inches, enabled Sir H. Davy to produce light and heat of the highest intensity. When the ends of the wire from each pile terminated in two charcoal points, the most dazzling light passed from the one to the other, and continued for several hours. Steel wires and thin leaves of different metals, were made red hot and burned, and water was boiled by plunging into it an iron wire two feet long and the one-hundredth of an inch in diameter, and placed between the poles of the battery. Platina, sapphire, quartz, lime, &c., when exposed to this source of heat, were instantly melted, and the diamond and charcoal disappeared as if they were completely volatilized. These effects were produced in vacuo as well as in air."

"At the same time that Mr. Children was constructing the greatest voltaic battery ever made, Dr. Wollaston was occupied in constructing the smallest. He took a small thimble, as we have already stated, and having

removed the bottom, he flattened the remaining cylinder till its sides were about one-sixth of an inch distant. He then placed between these two surfaces a small plate of zinc which did not touch either side of the thimble. With a platinum wire about one-fortieth of an inch long, and one-threethousandth of an inch in diameter, he united externally the plate of zinc, with this thimble; and when this little galvanic couple was immersed in acidulated water, the platinum wire became red hot, and was melted! This important result led Dr. Wollaston to the valuable conclusion, that in order to obtain powerful calorific effects, we must increase the surface of the copper or negative metal."

"In repeating the experiments of Davy on the light developed by charcoal points, Mr. Brandes discovered that this light, like that of the sun, affected the combination of chlorine and hydrogen, and the decomposition of muriate of silver and other bodies.

"By means of the powerful voltaic battery which Dr. Hare calls a *deflagrator*, and which we have already described, this able chemist obtained some splendid results. A brilliant light, equal to that of the sun, was produced between charcoal points; and plumbago and charcoal were fused * by Professors Silliman and Griscom. By a series of 250, baryta was deflagrated; and a platinum wire, three-sixteenths of an inch in thickness, 'was made to flow like water.' In the experiments with charcoal, the charcoal on the copper side had no appearance of fusion, but a crater-shaped cavity was formed within it, indicating that the charcoal was vola-

* This fusion of charcoal and plumbago has not been, we believe, by any means demonstrated. The volatilization of those forms of carbon may be also considered supposititious; conclusive evidence is wanting; these experiments show merely that a superficial disintegration and a partial modification of the solid is effected, and that some of the particles separated by the electric force are transferred from the one electrode to the other.

tilized at this side, and transferred to the other, where it was condensed and fused, the piece of charcoal at this pile being elongated considerably. This fused charcoal was four times denser than before fusion.

"Owing to its superior conducting power, a continued voltaic current will maintain in a state of incandescence a greater length of silver wire than of platinum or iron; but if we form a wire of short pieces of silver and platinum wire alternately, the platinum portion will become red hot, while the silver ones remain cold. In this case, the current which passes readily along the silver wire, encounters the degree of obstruction in the platinum which produces the red heat. The fact is no doubt connected with the very remarkable one observed by M. Peltier, in the passage of weak currents through metallic circuits, where *cold* was produced at the points of junction of certain crystallizable metals."

"Liquids, like solids, which are the worst conductors, are the most heated by electrical currents, a result arising from the resistance which the current experiences." *

"While in static electricity, we have the interesting phenomenon of the *electric spark*, already discussed in the article 'Electricity.' We have in voltaic electricity

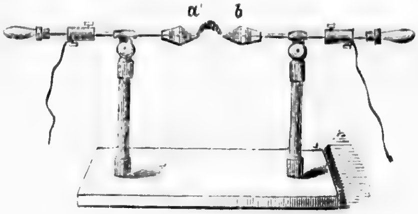


Fig. 56.

* This conclusion may be considered *hypothetical* . . . i.e., an opinion based on *hypothesis;* . . . it would be better to say 'a result which appears to be connected with a resistance experienced by the supposed current.'

the no less interesting phenomenon of the voltaic arch, which was discovered by Davy. It is represented at *a. b.* in the annexed figure, as produced between two charcoal points 4 inches distant, transmitting a current from 2000 pairs of zinc and copper, having each a surface of 32 square inches charged with acidulated water. It has the form of an arc convex above, and when the most refractory substances were placed in it, they became incandescent, and disappeared as if by evaporation. When one of the points *a.* was charcoal and the other *b.* plumbago, the particles of charcoal were transferred in the state of vapour to the plumbago, from the positive to the negative pole, and by interchanging the poles the plumbago was transported to the positive pole, as first shown by Dr. Hare.

The appearance and length of the arc varies with the nature of the *electrodes* or points *a. b.* between which it appears. Mr. Grove found that the longest and most brilliant arc, when shown in air, was produced when the electrodes were potassium, sodium, zinc, mercury, iron, tin, lead, antimony, bismuth, copper, silver, gold and platinum, the first giving the largest and brightest arc, and the rest as in their order. Mr. Grove also observed, that in vacuo the transported matter was in the state of metallic powder when the medium was hydrogen, nitrogen or a vacuum, and an oxide in air or in oxygen."

Sect. V. *On the Chemical Effects of Voltaic Electricity.*

"No sooner was this apparatus made known in England, than Messrs. Nicholson and Carlisle applied it to chemical enquiries. Although Volta had inferred from the shock that the action of the pile was electrical, yet it was to the above enquirers that we are indebted for determining, by means of the revolving doubler, that the *silver* end of the battery was in a *negative*, and the *zinc* end in a positive state of electricity. In the course of their experiments, they observed a disengagement of gas

which smelt of hydrogen, from water which happened to be in the circuit; and on the 2nd of May, 1800, they discovered that water was decomposed into its elements, viz., oxygen and hydrogen, when the water formed part of the circuit between the positive and negative ends of the pile." * * * *

"The attention of our illustrious countryman, Sir H. Davy, was about this time attracted to the subject. So early as 1802, he had made experiments on the chemical agency of the pile; but in 1806, in his first Bakerian Lecture, he was led to the conclusion, *that chemical attraction and repulsion were produced by the same cause, acting in the one case on particles, in the other on masses, and that the same property, under different circumstances, was the cause of all the phenomena exhibited by different voltaic combinations.*"

"With a voltaic battery of 200 plates, he decomposed several of the earths, and discovered their metallic bases, *barium, strontium, calcium* and *magnesium.*"

"In resolving a compound body into its elements, liquidity is an essential condition of the body. A plate of iron, the sixteenth of an inch thick, placed between the two sides of the pile, will stop completely the most powerful electrical current."

"By an irresistible body of evidence, Dr. Faraday has established the important proposition, 'that the chemical power of a current of electricity is in direct proportion to the absolute quantity which passes;' and this is true of all bodies capable of electro-chemical decomposition. The same eminent philosopher has also deduced, from a variety of facts, the following conclusion: 'that the quantity of electricity, which, being naturally associated with the particles of matter, gives them their combining power, is able, when thrown into a current, to separate these particles from their state of combination; or, in other words, that *the electricity which decomposes, and that which is evolved by the decompo-*

sition of a certain quantity of matter are alike.' According to this theory, 'the equivalent weights of bodies are simply those quantities of them which contain equal quantities of electricity, or have naturally equal electric powers, it being the *electricity* which determines the equivalent number, because it determines the combining force; or, if we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalents to each other in their ordinary chemical action, have equal quantities of electricity naturally associated with them."

ACOUSTIC FORCE (SOUND) AND ELECTRICITY.

Encyclopædia Britannica, on the vibratory movements and sounds produced by the Electric Currents.—So early as 1785, the Canon Gottoin, of Como, a friend of Volta's, observed that an iron wire, 30 feet long, when stretched in the open air, emitted a sound in certain states of the atmosphere. Page, Delezenne, Gassiot, and Marienini, observed sounds from electric currents under different circumstances; but it is to Delarive that we owe the most interesting experiments on the subject. When a magnetic but unmagnetized body, such as iron or steel, is placed in the interior of a bobbin, very remarkable rotary movements are produced by discontinuous currents passing through the wire which encircles the bobbin. Two sounds are always distinguished, one a series of blows or shocks, like the noise of rain falling on a metal roof, and the other musical. A mass of iron four inches in diameter, and weighing 22 lbs., placed within a large tube, gave out a very clear and brilliant musical sound; but the most brilliant of all are those obtained by stretching on a sounding-board well-annealed wires from three to six feet long, and one-fifteenth of an inch in diameter."

"A remarkable vibratory motion produced by electricity was observed by Mr. Fearn, of Birmingham, in

his electro-gilding establishment. When a brass tube 4 feet long and ½ inch wide in diameter was placed upon, and at right angle to, two horizontal and parallel brass tubes 9 feet long and an inch in diameter, and the latter connected with a strong voltaic battery of from two to twenty pair of large zinc and carbon elements, the transverse tube immediately began to vibrate, and finally to roll upon the other two.

Mr. G. Gore, who repeated the experiment under various circumstances, found that when the resistance was small and uniform, the rolling tube continued to move in the same direction imparted to it; but that when the resistances were not uniform, it continued to roll backwards and forwards as long as the electric current was passing.

In order to obtain a continuous rolling motion, Mr. Gore constructed the apparatus, where *A.* is a

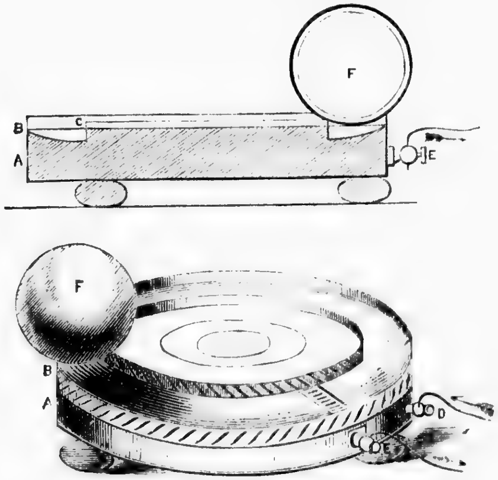


Fig. 57.

circular base of wood provided with two loose rails or hoops, *B.* and *C.* about one thirty-fifth of an inch thick, the outer one being one-fourth of an inch"

"higher than the other, and both being uniform and equidistant. *F.* is a perfectly round thin copper ball, hollow and equally thick, weighing about 500 grains.

When the circular base *E. A.* is made level, the ball *F.* placed upon the rails, and a voltaic current, copious in quantity and moderate in intensity, introduced at the screws *D.* and *E.*, the ball will begin immediately to vibrate, and increase its motions till it revolves upon the rails. It revolves with equal facility in either direction as long as the current is passing, and it becomes much heated during its motion. With three zinc and carbon batteries, the zinc cylinders being 6 inches high and 3½ wide, and strongly charged with dilute sulphuric and strong nitric acids, the ball was propelled at the rate of sixteen revolutions per minute.

'In all cases yet observed,' says Mr. Gore, 'the motion has been attended by a peculiar crackling sound at the surfaces of contact, and by the heating of the rolling metal; and in experiments on a large scale with thick tubes, strong vibrations, accompanied by the emission of musical sounds, were observed similar in a moderate degree to Trevelyan's experiment with heated metals. In a dark place, sparks appeared occasionally at the points of contact.' He considers 'the cause of the motion to be an intermittent thermic action taking place at the surface of contact, at a point a minute distance behind the centre of gravity of the rolling metal.'

Mr. Trevelyan's experiment here referred to consists in placing a heated bar of iron with one end on a solid block of lead. The bar in cooling vibrates considerably, and produces sounds similar to those of an Æolian harp. Prof. Forbes referred this class of vibrations to a repulsive action exercised in the transmission of heat from one body into another, which has a less power of conducting it; but having been led by Mr. Gore's paper to repeat the experiment, by passing an electric current through the hot and cold metal, he found that energetic vibrations"

"took place like those in the ordinary form of the experiment. The vibrations took place whatever was the direction of the electric current, and between metals of the same kind, as well as heterogenious metals. When a brass bar vibrating on cold lead is heated, and electricity applied as before, the effects are superadded to one another whichever way the current passes, and if there is a musical note it becomes grave. The effect from electricity he considers to be due to the repulsive action of the electricity in passing from the one metal to the other, which he regards as a confirmation of his explanation of the calorific vibrations. In extending his experiments, he found that carbon resting upon brass gave very energetic vibrations, and that bismuth is not merely inactive as a vibrator, but during the passage of electricity though it has a quelling power, which brings the vibrating bar to instantaneous rest."

On the physiological effects of Voltaic electricity.

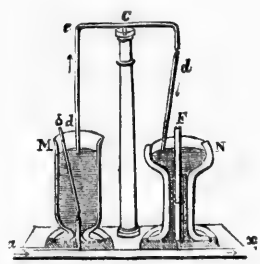
"A luminous spark is produced by voltaic electricity, when the eye forms part of the circuit. This may be done by placing a piece of silver between the gums and the upper lip, and inserting a silver probe into the nostrils. If a piece of zinc is then laid upon the tongue, and the two metals brought into contact, the flash will be seen."

"If a living leech, or an earthworm, is placed upon a crown piece laid upon a piece of zinc of a larger size, it experiences no uneasiness while it touches the silver only, but when it stretches itself and touches the zinc, it instantly draws back as if it had received a shock."

On Electro-magnetism.

"From these experiments, Prof. Oersted concluded *that the magnetical action of the electric current describes circles round* the conductors, and hence he gave the name of revolving magnetism to this magnetical action."

"The action of *revolving magnetism* was at first opposed by Prof. Schweigger, on the ground that if it were true, a magnet might be made to revolve round the uniting wire. Dr. Wollasten drew the same conclusion, but for the purpose of producing such a revolution. Before he had effected his purpose, however, Dr. Faraday, went a step further, and found experimentally that not only a magnet could be made to revolve around the uniting wire, but that a moveable uniting wire might be made to revolve round a magnet. An apparatus for exhibiting these remarkable properties is shown in Fig. 66. A wire *a.* from the voltaic battery passes into the glass vessel *M.* through a hole in its bottom, so as to communicate with mercury contained in the vessel. The lower end of a small magnet *b.* of the form of a cylinder is fixed by a thread to the bottom of the vessel, so that it floats almost vertically in the mercury. A wire *C. c. d.*



communicating with the other end of the battery, by means of the brass pillar *C.* dips with its lower end *d.* into the mercury in *M.*, and as soon as the voltaic current is established in the direction of the arrows, *a. d. e. C.* the pole *b.* of the magnet will revolve round the fixed conductor *d. e. C.*

The revolution of the conductor round a magnet is exhibited in the same figure, where *N.* is a glass vessel containing mercury, and having a small cylindrical magnet *F.* fixed to its bottom, and projecting a little above the surface of the mercury. The wire *d.* being attached by a hook to the horizontal arm *C.* will commence its revolutions round as soon as the voltaic current passes in the direction of the arrows, or *x. F. d. C.* If we make"

"the current pass in the direction *a. d. e. C. F. x.* from the zinc to the platinum end of the battery, both the above revolutions will go on similtaneously. When the current was made to pass in the opposite direction, the direction of the rotation was likewise changed.

"The rotation of liquid conductors may likewise, as Sir H. Davy has shown, be produced by the pole of a magnet. If mercury is placed in a shallow dish between the two poles of a battery, a magnet placed either above or below the mercury, will cause the mercury to revolve round the points from which the currents issue. The rotation of the flame produced by the passage of a powerful voltaic charge between two charcoal points, arises from the same cause. Prof. Daniell gives the following pleasing method of showing the effect. He makes a powerful horseshoe magnet part of the conducting wire of a constant battery of a moderate number of cells; the flame which may then be drawn from one of its poles will revolve in one direction, while that from the other will revolve in the opposite direction."

"Various forms have been given to these electro-dynamic cylinders. In some the coils all lie in one plane, as in Fig. 71,* where one face of the coil has north, and the other south polarity, the magnetic poles being as it were situated in the centre of each disc.

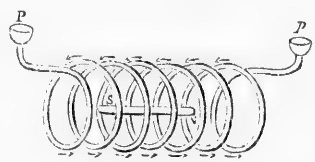


Fig. 72.

When the helix is constructed, as in Fig. 72, its power is so great that a small steel bar *S. N.* placed within it, and supported perpendicularly, will, as soon as the connection is made with the voltaic battery, by means of the mercury cap, *P. p.* start up, and place itself in the air,"

* See page 220.

" where, like Mahomet's coffin, it will remain suspended without any visible cause, and in opposition to the power of gravitation.

We owe also to M. Ampere the very interesting apparatus of a small voltaic battery made to revolve round a magnet. This is shown in Fig. 73, where *A. B. C. D. a. b. c. d.* exhibits a section of two cylinders of copper soldered to a copper bottom, so as to hold a fluid. The double cylindrical vessel is suspended by a bent wire *a. F. b.* (having a cavity at *F.*,) upon the north pole *N.* of a vertical magnet *N. S.* A light cylinder of zinc *z. z.* is also so suspended by a bent wire *z. E. z.* and a steel pivot at *E.* upon the same pole N. of the magnet. The cylinder *z. z.* can therefore revolve upon this pivot. When the cylinder *A. B. D. d. a. b. c.* C. *A.* is filled with dilute acid so as to constitute a small battery, the cylinder *z. z.* will revolve from left to right when *N.* is the north end or south pole, and from right to left when *N.* is the south end or north pole. Owing to the attraction of the fluid, the cylinder of zinc is often drawn to one side, and prevented from moving; but this may be avoided by making the space *A. c.* sufficiently wide. Mr. Watkins has ingeniously applied this contrivance to the poles of a horse-shoe magnet, as in Fig. 74.* It consists of a horse-shoe magnet *A. B.* fixed to a stand *S. S.* Above each pole is suspended a double cylindrical copper vessel, with a bent metallic wire fixed to the top of the inner cylinder, and a vertical wire, pointed at each extremity, fixed in the middle of the bent wire. The lower ends of the vertical wires of each cylinder rest in the holes of each olpe of the magnet. Within the above double copper vessels are placed two hollow cylinders of zinc, having similar bent "

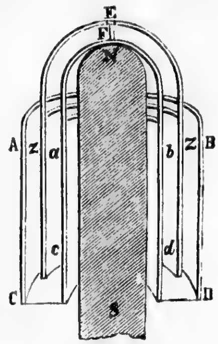


Fig. 73.

* See page 220.

"wire with holes in the lower side of each, in which holes the upper ends of the vertical wires are inserted. When the copper cylinder is filled with dilute acid, the voltaic action begins, all the four cylinders revolving round their respective axes. The copper cylinders turn slowly and heavily, from their weight, in opposite directions to one another, and the zinc cylinders, with great velocity, in opposite directions to the copper ones. Very delicate suspensions are necessary to ensure the rotation of the copper cylinders.

A very simple apparatus for shewing the magnetic state of a single coil is shown in Fig. 75, where *Z.* and *C.* represent the elements of a small galvanic battery of one zinc and one copper plate attached to a cork which floats on dilute acid. Each plate is half an inch wide, and two inches long. A piece of copper wire *W.* with silk thread wrapped round it, is bent into a ring, one end of which is soldered to the zinc, and the other to the copper plate.

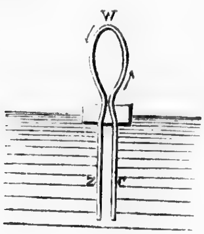


Fig. 75.

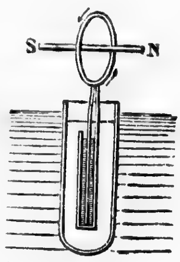


Fig. 76.

An electric current now passes in the direction of the arrow, and the ring *W.* becomes a flat magnet, having its poles in the centre of its two surfaces, the one being north and the other south. This floating magnet will, when acted upon by a real magnet, exhibit the usual magnetic attractions and repulsions. Mr. Marsh has improved this apparatus by doubling the copper plate as in Fig. 76, and converting it into a vessel for holding the"

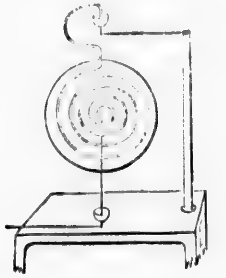


Fig. 71.

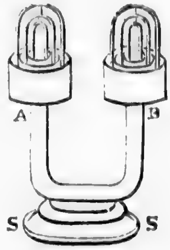


Fig. 74.

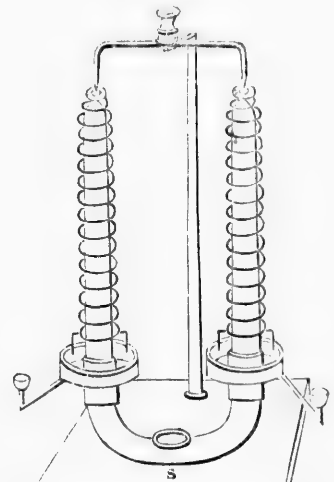


Fig 77.

"dilute acid. The plates are then placed in a glass cylinder which may float in water." *

The magneto-electric machine has been greatly improved by Mr. E. M. Clarke, magnetical instrument maker, London. † It is represented in Fig. 94, where *A.* is the battery of bent bar magnets resting against the vertical board *B.*, and by means of a bar of brass *C.*, with a bolt and screw-wheel, the magnets can be drawn firmly to the board *B.* or taken from it. One of the keepers or armatures *D.* is screwed into a brass mandrill between the poles of the magnets, and it is made to revolve by the multiplying wheel *E.* This armature has two coils of fine copper wire, 1500 yards long, wrapped round its cylinders, the beginning of each coil being soldered to the armature *D.*, from which also projects a brass stem carrying the break-piece *H.*, which can be fastened in any required position by a binding screw; a hollow brass cylinder *K.*, to which the ends of the coils are soldered, being insulated by means of a piece of hard wood attached to the brass stem. An iron wire spring *O.* passes at one end against the cylinder *K.*, and is kept in contact with it by a screw in a brass strap *M.* in the wooden block *L.* A square brass pillar *P.* fits also a square opening in the other brass strap *N.*, on the other side of the block *L.* A metallic spring *Q.* rubs gently upon the break piece *H.*, and is retained in perfect metallic contact with it by a screw in the pillar *P.*, the two straps of brass *M. N.* are connected by a piece of copper wire *T.*, and in this state the parts *D. H. Q. P. N.* are in connection with the commence-"

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* "A very beautiful apparatus for exhibiting helical rotation has been constructed by Mr. Watkins, and is shown in Fig. 77." It is thought that the figure will for the present purpose sufficiently explain itself as a modification of those preceding it.

† This improved form of the M. E. machine may be compared with that already illustrated at page 168 from Fownes' Manual of Chemistry. The illustration is repeated on the same plate at Fig. 96.

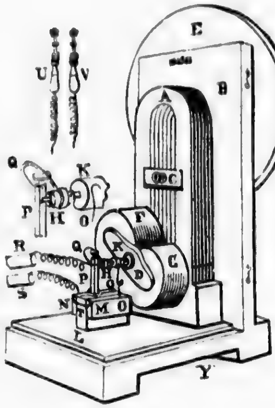


Fig. 94.

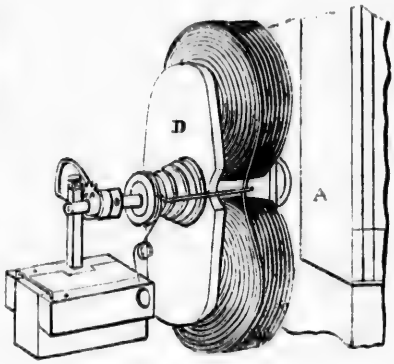


Fig. 95.

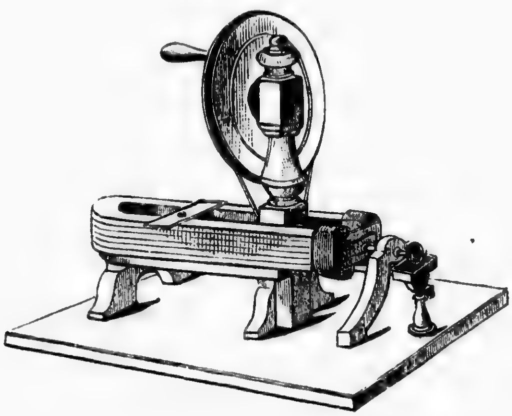


Fig. 96.

" ment of each coil, and the parts *K. O. M.* with the termination of each coil. The perfect metallic contact thus obtained by the spring and break, enables Mr. Clarke to dispense entirely with the use of mercury, which is at all times a troublesome accompaniment of machinery.

But the great superiority of Mr. Clarke's machine arises from his employing two different armatures, and thus being enabled to produce the separate effects of quantity and intensity to the full extent of the power of his battery. Having, in November, 1834, tried the effects of coils of wire of different thicknesses, he found that the thick copper bell wire gave brilliant sparks, but no perceptible shock, while very fine wire gave powerful shocks, but very feeble sparks.

By means of the *intensity armature*, which is that shown in Fig. 94, the various experiments made with a number of separate galvanic plates may be performed, while the intense agony produced by its shocks is intolerable: it can, at the same time, (?) electrify the most nervous person without occasioning the least uneasiness. It decomposes water and the neutral salts. It deflects the gold leaves of the electroscope, charges the Leyden jar; and by an arrangement of wires from the mercury box to the battery, the electricity is made visible, passing from the magnetic battery to the armature, and sparks and brilliant scintillations of steel can be obtained.

The *quantity armature* differs greatly from the intensity one, as shown in Fig. 95, which exhibits the method of producing the spark.

The weight of the iron in the cylinders is much greater than in the intensity one, the copper wire is much thicker, and its length is only forty yards. By this armature all the experiments can be made which are usually performed by a single pair of voltaic plates of large surface, or by a calorimotor; but it will not do for "

"any of the intensity experiments. It produces such large and brilliant sparks, that a person can read small print from the light it produces. It ignites gunpowder and platinum wire, without enclosing the wire in a hermetically sealed glass case. It deflagnates gold and silver leaf, and produces brilliant scintillations from a small steel file. It produces also rotatory motions in delicately suspended wire frames round the poles of a vertical horseshoe magnet and all the other effects of voltaic electricity.

Although the law which governs the evolution of electricity by magneto-electric-induction is very simple, yet Dr. Faraday has found it rather difficult to express it, except in reference to diagrams. We shall therefore give it in his own words: "If in Fig. 89, *P. N.* represent a horizontal wire passing by a marked magnetic pole so that the direction of its motions shall coincide with the curved line proceeding from below upwards; or if its motion parallel to itself be in a line tangential to the curved line, but in the general direction of the arrows;

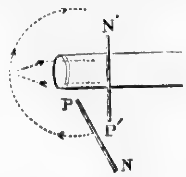


Fig. 89.

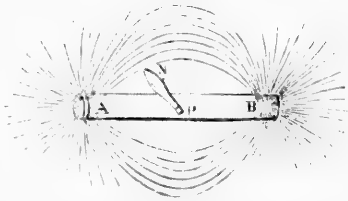
or if it pass the pole in other directions, but so as to cut the magnetic curves* in the same general direction, or on the same side as they would be cut by the wire if moving along the dotted curved line; then the current of electricity in the wire is from *P.* to *N.* If it be carried in the reverse direction, the electric current will be from *N.* to *P.* Or if the wire be in the vertical position, as at *P.' N.'*, and it be carried in similar directions, coinciding with the dotted horizontal curve, so far as to cut the magnetic curves on the same side with it, the current"

* "By magnetic curves, I mean the lines of magnetic forces, however modified by the juxtaposition of poles, which would be depicted by iron filings, or those to which a very small magnetic needle would form a tangent."

"will be from *P.'* to *N.* If the wire be considered a tangent to the curved surface of the cylindrical magnet, and it be carried round that surface into any other position, or if the magnet itself be revolved on its axis, so as to bring any part opposite to the tangential wire; still, if afterwards the wire be moved in the directions indicated, the current of electricity will be from *P.* to *N.*; or if it be moved in the opposite direction, from *N.* to *P.*; so that as regards the motions of the wire past the pole, they may be reduced to two, directly opposite to each other, one of which produces a current from *P.* to *N.* and the other from *N.* to *P.*

"The same holds true of the unmarked pole of the magnet, except that if it be substituted for the one in the figure, then, as the wires are moved in the direction of the arrows, the current of electricity would be from *N.* to *P.*, and when they move in the reverse direction from *P.* to *N.*

"Hence the current of electricity which is excited in metal when moving in the neighbourhood of a magnet, depends for its direction altogether upon the relation of the metal to the resultant of magnetic action, or to the magnetic curves, and may be expressed in a popular way, thus: Let *A. B.* (Fig. 90) represent a cylinder magnet, *A.* being the marked pole, and *B.* the unmarked pole; let *P. N.* be a silver knife-blade resting across the magnet, with its edge upward, and



with its marked or notched side towards the pole *A.*; then in whatever direction or position this knife be moved edge foremost, either about the marked or the unmarked pole, the current of electricity produced will be from *P.* to *N.* provided the intersected curves proceeding from *A.* abut"

"upon the notched surface of the knife, and those from *B.* upon the unnotched side. Or, if the knife be moved with its back foremost, the current will be from *N.* to *P.* in every possible position and direction, provided the intersected curves abut on the same surfaces as before. A little model is easily constructed, by using a cylinder of wood for a magnet, a flat piece for the blade, and a piece of thread connecting one end of the cylinder with the other, and passing through a hole in the blade, for the magnetic curves; this readily gives the result of any possible direction.* When the wire under induction is passing by an electro-magnetic pole, as, for instance, one end of a copper helix traversed by the electric current, the direction of the current in the approaching wire is the same as that of the current in the parts or sides of the spirals nearest to it, and in the receding wire the reverse of that in the parts nearest to it.

All these results show that the power of inducing electric currents is circumferentially exerted by a magnetic resultant, or axis of power, just as circumferential magnetism is dependent on, and is exhibited by, an electric current."

NOTE.*—We are afraid it is less easy to correctly understand than to misunderstand this explanation. The following clearly expressed statement from *Fownes' Manual of Chemistry*, may enable (or assist) the reader to correctly appreciate what is intended in the foregoing:

"The action which a current of electricity, from whatever source proceeding, exerts upon a magnetized needle is quite peculiar. The poles or centres of magnetic force are neither attracted nor repelled by the wire carrying the current, but made to move *around* the latter, by a force which may be termed tangential, and which is exerted in a direction perpendicular at once to that of the current, and to the line joining the pole and the wire. Both poles of the magnet being thus acted"

"upon at the same time, and in contrary directions, the needle is forced to arrange itself across the current so that its axis, or the line joining the poles, may be perpendicular to the wire; and this is always the position which the needle will assume when the influence of terrestrial magnetism is in any way removed. This curious angular motion may even be shown by suspending a magnet in such a way that one only of its poles shall be subjected to the current; a permanent movement of rotation will continue as long as the current is kept up, its direction being changed by altering the pole, or reversing the current. The moveable connections are made by mercury, into which the points of the conducting-wires dip. It is often of great practical consequence to be able to predict the direction in which a particular pole shall move by a given current, because in all galvanoscopes, and other instruments involving these principles, the movement of the needle is taken as an indication of the direction of the circulating current. And this is easily done by a simple mechanical aid to the memory: Let the current be supposed to pass through a watch from the face to the back; the motion of the north pole will be in the direction of the hands, or a little piece of apparatus may be used if reference is

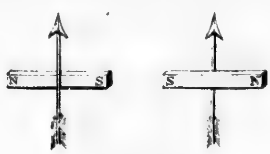


Fig. 68.

often required; this is a piece of pasteboard, or other suitable material, cut into the form of an arrow for indicating the current, crossed by a magnet having its poles marked, and arranged in the true position with respect to the current. The direction of the latter in the wire of the galvanoscope can at once be known by placing the representative magnet in the direction assumed by the needle itself."

On the Applications of Electro-Magnetism.

Encyclopedia Britannica.—"The power of electric currents to develop magnetism in soft iron is so great as to have led several philosophers to apply it to the production of a continuous movement, either rotatory or reciprocating. M. Jacobi, of St. Petersburg, was the first who constructed such a machine, and it was for a long time used in impelling a boat on the Neva. Since that time many electro-motors, as such machines are called, have been constructed; the most important of these are by Loiseau, Froment, Lamanjeau, Page, and Dumoncel. The late Mr. Sturgeon pumped water with an electro-magnet; Mr. Davidson, of Aberdeen, drove a turning-lathe by the same power; and in 1848 we sailed at the rate of a mile in the hour in a boat thus impelled and constructed by Mr. Dillwyn, of Swansea.

M. Jacobi, as we have stated, has been led by Dr. Faraday's discovery of magnetic electricity to abandon his expectation of obtaining anything like a valuable power from electro-magnetism; and Messrs. Joule and Scoresby have come to the same conclusion. It appears from their calculations that a grain of coal consumed by a steam-engine in Cornwall will raise 143 lb. 1 foot, whilst a grain of zinc consumed in a voltaic battery can raise theoretically only 80 lbs. But the price of an hundred weight of coal is less than 9 pence, whilst that of the same quantity of zinc is more than 216 pence, so that, under the most favourable conditions, the power obtained from electro-magnetism must cost twenty-five times as much as that from steam."

Now herein we have a conclusion arrived at on a question of great importance in connection with the progress of civilization in, what may be called, a practical and material sense, as well as in a more highly intellectual sense; an unfavourable conclusion of a very grave

and serious practical character, because the mechanical artist or inventor, who at first supposes that out of the resources of nature, a novel means of obtaining his primary power (force), much superior to any hitherto known, has been brought to light and placed in his hands, is checked, and not only discouraged, but, authoritatively informed it is useless for him to attempt to utilize this novel means, for that—instead of superior—it is very much inferior to the older means already in use, and that the inferiority is not of the character of a difficulty which perseverance and increased skill may, and therefore can, overcome, but is a natural inferiority and in the nature of things, insuperable. To the practical artist therefore the following question is of great interest:—Is it quite certain that the decision is a sound one? Is the conclusion supported and justified by the natural facts? To this question we may briefly but decidedly reply that the above conclusion is not so justified and is not supported by fact. Neither the discoveries of Faraday, nor those of any one else, properly applied, demonstrate such a proposition, but quite the contrary.

The nature of the calculation cited by the writer in the Encyclopedia, makes apparent that the conclusion has been come to through confounding with each other cases which are essentially different. Thus it is quite true, for instance, if we were to apply molecular electricity to decompose water into its elements, and then make use of the expansive force, of the compressed gases thereby disengaged, as a motive (mechanical) power, that the calculation and conclusion would have a sound application to such a proceeding; because it has been ascertained that to develop a certain definite quantity of molecular electricity, the consumption of a certain quantity of zinc or other material is requisite, and the definite quantity of the electricity developed can only decompose a limited and definite quantity of water . . a quantity which is directly proportional, in the ratio of the elemen-

tary equivalents, to the quantity of the zinc (or other material) consumed in the battery, and therefore the case is quite similar to that of the conversion of water into steam by the combustion of coal; for therein, also, a definite quantity of the coal consumed, developing a definite quantity of caloric force, disengages a proportional quantity of gaseous water, of which the expansive force is available as the primary mechanical power. But in electro-magnetism the case is no longer similar. The consumption of a certain definite quantity of zinc will still develop only a definite quantity of molecular electricity as before, but the quantity of mechanical effect which can be obtained from this quantity of electricity through the magnetic power induced by it is not limited in the same manner; . . given a wire conducting molecular electricity, of any intensity,—this wire being coiled around a bar of soft iron induces magnetism therein, but, the greater the number of coils, the greater the intensity of the magnetic force conferred upon the iron; and further, the length of the wire being indefinitely great, it may be coiled around a second bar of iron, and the same electricity which has induced the magnetic power (force) in the first, confers also the same property on the second; but, the length of the wire being indefinitely great, instead of two bars we may take ten, or a hundred, or a thousand, or ten thousand, without hindrance by any natural (theoretical) limitation: the electricity is the same in quantity as at first, is just as active, and just as available after having magnetized a hundred bars as after magnetizing one; and, again, if the circuit be suddenly broken the (so-called) induced current through the wire in the opposite direction is a source of mechanical power limited only by the length of the wire, which may be indefinitely great. In mechanical science the equality of action and effect as a fundamental law is very well established, and it is inconsistent with that law to suppose that the quantity of effect can be any

greater than the quantity of action (power); for instance, a weight of one pound descending through one foot in one second, represents or develops a certain quantity of mechanical action (power), and this quantity is theoretically capable of producing a quantity of effect precisely equal to itself; but practically, as applied through a machine, a part of the power is employed in overcoming the friction of the moving parts, and the apparently useful effect obtained is a little less (often much less) than the whole quantity of active power; but no combination of levers or refinement of machinery can obtain a quantity of effect greater in any degree whatever than the quantity of action (active force) employed.

Now it is very easy to misapprehend the significance of this law and to argue that the utilization of the effect is a use of the active force (action); meaning, thereby, that the force is *used* in the sense of 'used up,' 'consumed,' 'converted' into *effect* . . . *i. e.*, into *something else*, and, consequently, is no longer existent as force or power. Such inference is not supported by fact, and is unreasonable. If the descent of one weight is employed in raising another . . the power or force is merely transferred from the first to the second; (it may or may not be equally available for further employment, but it is existent . . all of it, and theoretically available.) So in the steam engine . . the steam having performed its office (produced its mechanical effect) has not necessarily lost any of the caloric-force derived by it, as water, from the combustion of the coal. If all the heat could be now abstracted from the waste steam it might be re-applied to repeat the effect, and so on, for an unlimited number of times. In practice only a small part of the caloric-force (or steam power) can be thus made again available, but even this small part . . namely, that portion of the waste steam used to heat the water supplying the boiler or the air supplying the furnace . . is sufficient to demonstrate the proposition that *action* (meaning thereby *mechanical force*

or *power*) is not converted into the equivalent effect, in the sense of being, by such conversion, '*used up*,' and *consumed*.

Mechanical effect is a manifestation of active force overcoming resistance: the resistance having been overcome, the force is no longer active, it becomes quiescent or latent; but, the force is neither lost nor consumed. The great superiority of electro-magnetism as a source of mechanical power consists in its affording the means of obtaining an unlimited number of repetitions of effect from any given quantity of active force. So far from electro-magnetism being unable as a source of motive power to compete with coal, it is quite evident that in such competition the caloric-force derived from coal must be very soon superseded by the much more advantageous and more readily available force of molecular electricity. It is, however, quite apparent that if we have now arrived at a time when molecular electricity can be, without much difficulty, made available for the purposes of civilized life, it is because a certain degree of civilization and of skill in the mechanical arts has been acquired and a certain amount of scientific knowledge has been obtained. For the earlier stages of human civilization, such as our predecessors have passed through, the enormous benefit of an abundant coal supply could be scarcely overestimated; it seems, indeed, difficult, on looking back, to imagine such progress to have been, humanly speaking, possible without such a supply of readily available fuel.

Assuming, as we may do, that the use of coal for many of the purposes in which it has been employed will be now very soon superseded — it will not be out of place here to remind those of our readers who have paid some attention to the geological record of the earth's history .. of the long and careful preparation of that important element of our welfare as a civilized race ... of the long Carboniferous Period, with its luxuriant vegetation ... of

the teeming and almost numberless successive generations of Lepidodendra and Sagillariæ, by means of which the carbon was taken from the atmosphere and made ready for the final conversion . . . of the long and changeful Permian Period, and . . . of those great disturbances of the earth's surface, belonging to that period, in which the preparation was completed, and the final conversion into beds of coal was consummated.

There have not been wanting some persons of education and partial scientific knowledge who, with a strange forgetfulness of One whose work is not imperfect, and whose plans do not fail, have fearfully predicted the exhaustion of the coal supply, and the consequent collapse of the material prosperity of the civilized world. The Verbal Record states that He who made the heavens and the earth hath also expressly declared that the earth has not been created in vain, and was made to be permanently inhabited. We believe the record and the declaration undoubtingly; and we understand that declaration to include the meaning that ample provision has been or will, when necessary, be made for the continued progressive advancement of (terrestrial) human civilization. Such fears and predictions are therefore according to our belief not only unreasonable, but also unseemly, and they certainly do not belong to science. There may be indeed, a sufficient basis for fear and apprehension of danger, but if the fear is to be justified by the event and the danger is to become a catastrophe, it will be again, as it has been in former times, occasioned by the wilfulness, the superstition, and intellectual depravity of those who, having acquired knowledge, pervert and misuse it, who, disregarding responsibility and contemning law, systemize untruth and organize deceit.

The coal is not nearly exhausted.

If that deplorable catastrophe, which has already happened more than once, shall yet again overtake

mankind . . . if the floods of disorder, anarchy and materialism, are again to overwhelm and destroy the intellectual vitality of the whole human race, and knowledge, escaping only by the providence of the Creator, is again to be left with the elementary rudiments of science, alone to replenish the earth ; . . . if the present terrestrial civilization is to be condemned as hopelessly corrupt and thus to share the fate of its predecessors ; who shall say there is not sufficient coal, in the vast deposits of this continent only, to supply the necessities of those who, it may be, are destined to renew the attempt to acquire knowledge and with it to acquire the recognition of the responsibilities belonging to knowledge . . . of those who, perhaps, are destined to succeed where we have failed, and to establish on the earth a permanent intellectual civilization, sound, uncorrupt, and possessing the essential requirements for a safe and progressive development.

We do not, however, believe in the intellectual failure of the present race, nor do we expect the destruction of the existing civilization.

That the present is a time for apprehension because a time of critical danger, there can be no reasonable doubt, but, no intellectual catastrophe of a general character will take place unless each and every nation deliberately declares itself by and through the medium of its intellectual representatives as wilfully preferring falsehood to truth, and as determined to disregard the laws of intellectual existence.

That such a determination will be deliberately concurred in by the nation to which we belong, we cannot, and do not, suppose.

END OF THE APPENDIX.